2012

The Importance of Water-Based Ecosystem Services Derived from the Shoshone National Forest

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THE IMPORTANCE OF WATER-BASED ECOSYSTEM SERVICES DERIVED FROM THE SHOSHONE NATIONAL FOREST

By

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Thesis

Presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Major, Resource Conservation

The University of Montana
Missoula, MT

December 2012

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The Importance of Water-Based Ecosystem Services derived from the Shoshone National Forest

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There is a wide range of goods and services being provided to humans by water resources (e.g. hydropower and recreation), but there is also a diversity of stakeholders that require or desire these benefits, also known as water-based ecosystem services, for everyday life. Land managers working for the United States Department of Agriculture Forest Service in the semi-arid Rocky Mountain Region are tasked with the difficult job of managing scarce water resources in the face of competing human pressures and natural forces (e.g. climate change).

Water management decisions on public lands can potentially impact the availability of a wide range of benefits derived from water to a wide range of stakeholders. This project aimed to inform policy-makers and land managers about the range of benefits people derive from water within and flowing from the Shoshone National Forest (SNF), and the importance of those water benefits to stakeholders in northwest Wyoming. Additionally, this project aimed to understand the perceptions of stakeholders regarding the threat of climate change, and other factors, to their ability to receive certain water-based ecosystem services.

The use of literature review, focus groups, and pilot tests helped to identify 34 water-based ecosystem services being derived from the SNF. An understanding of stakeholder preference for those 34 ecosystem services was obtained through the use of a preference elicitation method called Q-methodology, which was administered to 96 stakeholders covering a broad range of interests. Factor analysis of the 96 surveys yielded four major perspectives that explain, in a nuanced fashion, 48% of the study variance. The four viewpoints were named the environmental perspective, agricultural perspective, Native American perspective, and recreation perspective. The preferences for each of the four viewpoints with regard to water-based ecosystem services are presented holistically, however, each of the viewpoints is partly defined by two 'most important' ecosystem services. Those 'most important' water-based ecosystem services were water quality ('most important' to two different viewpoints), household/municipal use ('most important' to two different viewpoints), Native American cultural and spiritual values, commercial irrigation, river-based fishing, and biodiversity conservation.

The threat of climate change to the ability of stakeholders to receive their most important water-based ecosystem services was acknowledged by the majority of stakeholders but, in many cases, there was skepticism that climate change is anything more than a natural trend. Additionally, stakeholders were concerned about water quality, federal and state government management and regulations (e.g. reservoirs and in-stream flow management), and other competing uses impacting their ability to receive their most important ecosystem services.

Acknowledgements

First and foremost, a large thank you goes out to all of the participants who donated their valuable time throughout this project, which could not have been completed without the participation of so many in focus groups, pilot tests, and surveys. I also need to thank my committee, which was integral in the completion of this project. Thank you to my co-Chair, Dr. Neil Moisey, who was responsible for my admission into this great University, and who was constantly giving me advice about the necessary steps to take throughout the program. Thank you to my co-Chair, Dr. Tyron Venn, who worked tirelessly on editing and commenting on the many drafts of this project, and who never considered a detail to be too small. I can honestly say that without Tyron, this project would be of a much lower caliber, if finished at all, and I would still be a novice writer trying to understand the difference between two, to, and too. A thank you to Dr. Alan Watson, of the United States Department of Agriculture – Rocky Mountain Research Station - Aldo Leopold Wilderness Research Institute, for taking the time early in my graduate career to sit down and talk about potential thesis projects, and then taking those conversations a step further by including me on this funded project. Also, thank you Alan for your help throughout this project, whether it was setting up a meeting with the Forest Service in Cody, or asking critical questions about the direction of the research. Thank you to the last of the committee members (but certainly not least), Dr. Sarah Halvorson, for her outside-the-box thinking, suggestions for obscure readings, responsiveness to all of my inquires, and encouragement.

There are a few thanks that need to be offered to those people who facilitated the writing process of this project. A big thank you to Jon Rieck of the Rocky Mountain Research Station in Missoula for donating his time and GIS skills, without his help the maps for this study would not exist. Thank you to Linda Joyce of the Rocky Mountain Research Station in Fort Collins for taking the time to read through my study plan, and for offering so many great suggestions that ultimately improved my approach to this project. Thank you to the Q-methodology listserv, which served as an invaluable resource for learning about the method. Specifically, thanks to Dr. Steven Brown and Bob Braswell for taking the time to thoughtfully and thoroughly respond to my Q-uestions on the listserv.

A number of thanks are in order for individuals who live within the study area of this project, and were helpful in facilitating the on-the-ground research process. Thanks to Carrie Christman and Karri Cary of the Forest Service in Cody, WY, who helped to set up meetings throughout the research process, and were always willing to impart their local knowledge of the study area. Thanks to Jim Real Bird and John Doyle of the Crow Indian Reservation, who were helpful in facilitating my research on the Reservation by putting me in contact with potential participants, and who made me feel welcome during my time on the Reservation. Thanks also to Wes Martel and Baptiste Weed on the Wind River Indian Reservation, who helped my research process by recruiting participants on the Reservation, and for their tolerance of my many inquires. Thanks to Steve and Maurine Cole for allowing me to live in their home for several weeks during the data collection process, and for raising such an understanding daughter. Thank you, Stephanie, for your patience during this all-consuming process.

Table of Contents

Abstract ii
Acknowledgments iii-iv
Table of Contents v-x
List of Figures xi-xii
List of Tables xiii-xiv

1. Introduction 1
- 1.1 Problem Statement and Motivation for the Study 1
- 1.2 Research Objectives 4
- 1.3 Justification 5
- 1.4 Layout of Thesis 9

2. Literature Review of Ecosystem Services and Climate Change Concepts 11
- 2.1 Ecosystem Services 12
  - 2.1.1 Classification of ecosystem services by function 12
  - 2.1.2 Classification of ecosystem services by value 16
  - 2.1.3 The utility of employing an ecosystem services framework 20
- 2.2 Climate Change 21
  - 2.2.1 Perceptions of the United States adult population regarding climate change 21
  - 2.2.2 Climate change vulnerability 26
    - 2.2.2.1 Defining vulnerability in the climate change context 26
    - 2.2.2.2 Models for assessing vulnerability 29
  - 2.2.3 Climate change impacts: A global outlook 31
  - 2.2.4 Climate change modeling 34
    - 2.2.4.1 Brief history of global climate models 35
    - 2.2.4.2 Limitations of climate modeling 36
    - 2.2.4.3 Predicting the future state of the climate 37
    - 2.2.4.4 Regional and local climate models 39
    - 2.2.4.5 Potential modeling approaches for a study focused on water resources 43
    - 2.2.4.6 Relevant data inputs for modeling the impact of climate change on study area water resources 44
- 2.3 Summary 48

3. Research Setting 51
- 3.1 Geography of the Study Area 51
  - 3.1.1 Study area boundaries 52
  - 3.1.2 Water resources, topography and vegetation 55
  - 3.1.3 Climate 58
  - 3.1.4 Human geography 59
- 3.2 Socio-economic Attributes of the Study Area 61
  - 3.2.1 Unemployment and income statistics 61

3.2.2 Contribution of water-related industries to total employment 62
3.2.3 Economic significance of various water-related industries within the study area 64
3.2.3.1 Oil and natural gas extraction, and mining 65
3.2.3.2 Tourism and recreational activities 67
3.2.3.3 Agriculture 68
3.3 The culture of water within the study area 69
3.3.1 Brief history of water development in Wyoming and the study area 70
3.3.2 Native populations and water within the study area 73
3.3.3 Relationship between oil and gas extraction, and water resources in the study area 75
3.4 Climate Change and Water within the Study Area 78
3.4.1 Observed impacts of a changing climate on water resources in the study area 78
3.4.1.1 Timing of snowmelt 79
3.4.1.2 Earlier onset of spring 79
3.4.1.3 Frost-free days and the growing season 81
3.4.1.4 Melting of glaciers 82
3.4.1.5 Reduced snowpack and changes in precipitation type 83
3.4.1.6 Extreme precipitation and temperature events 84
3.4.2 Climate change vulnerability and implications for water-based ecosystem services within the study area 87
3.4.2.1 Implications for fishing, hunting and recreational water-based ecosystem services 88
3.4.2.2 Implications for agriculture and hydropower 90
3.4.2.3 Implications for glacier-based services, gradual discharge of stored water and natural flood control 91
3.5 Summary 92

4. Theoretical Foundation and Procedure of Q-Methodology 93
4.1 General Description and Applications of Q-Methodology 93
4.2 Procedure for Q-Methodology 95
4.2.1 Creation of the concourse and Q-set 96
4.2.2 Creation of the Q-board 100
4.2.3 Recruitment of Q-sort participants 105
4.2.4 Completion of the Q-sort by participants 110
4.2.5 Data analysis 112
4.2.5.1 Factor analysis 112
4.2.5.2 The covariance matrix 113
4.2.5.3 Extraction of initial factors 120
4.2.5.4 Factor rotation 135
4.2.5.5 Generating factor arrays from factor scores 141

4.2.5.6 Factor interpretation and articulation of results 144
4.3 Evaluation of Alternative Stakeholder Preference Elicitation Methods 154
4.3.1 Case study example that employed random sampling 155
4.3.2 Decision-analytic methodology 156
4.3.3 Analytic hierarchy process 157
4.3.4 Likert-scale survey research 159
4.3.5 Contingent valuation method 160
4.4 Summary 162

5. Application of Q-Methodology for Elicitation of Stakeholders' Preferences for Water-based Ecosystem Services Derived from the Shoshone National Forest **165**
5.1 Concourse, Q-set and Q-board Development 165
5.1.1 Criteria for development of concourse and Q-set 166
5.1.1.1 Naturalness criterion 168
5.1.1.2 Blue-water criterion 170
5.1.1.3 Management criterion 171
5.1.1.4 Conflict criterion 172
5.1.2 Development of the concourse and Q-set via literature review 173
5.1.3 Development of the concourse and Q-set via focus groups 176
5.1.4 Finalization of the Q-set via informal discussions and pilot tests 178
5.1.5 Construction of the Q-board 180
5.2 Stakeholder Identification and Recruitment 182
5.3 Administration of Surveys 185
5.4 Data Analysis 189
5.4.1 Data entry 189
5.4.2 Factor analysis or PCA? 190
5.4.3 Extraction of unrotated factors 191
5.4.4 Rotation of factors and flagging 192
5.4.4.1 Choosing a rotated-factor solution 193
5.4.5 Interpretation and articulation of the chosen rotated-factor solution 194
5.5 Drivers Discussion 197
5.6 Summary 198

6. Results of a Q-Methodology Study on Water-based Ecosystem Services derived from the Shoshone National Forest 199
6.1 Concourse and Q-set 199
6.1.1 Focus group expansion of the concourse into the Q-set 203
6.1.2 Results of using pilot tests and informal discussions to finalize the Q-set 213

6.1.3 Classifying the water-based ecosystem services in the Q-set by function 215
6.2 The P-set 217
6.2.1 Demographic attributes of the stakeholders 220
6.2.1.1 Age, race, education, and work status 220
6.2.1.2 Location of residence and type of household 223
6.2.1.3 Work history, and membership in organizations 225
6.2.1.4 Recreational pursuits 226
6.2.1.5 Household and workplace supplies of water 227
6.3 Results of Data Analysis 229
6.3.1 Deciding on a rotated-factor solution 230
6.3.2 Results of factor analysis and principal components analysis 239
6.3.3 Interpretation and articulation of the three-factor solution 241
6.3.3.1 Factor 1: the environmental perspective 241
6.3.3.2 Factor 2: the agricultural perspective 250
6.3.3.3 Factor 3A: the Native American perspective 257
6.3.3.4 Factor 3B: the recreation perspective 263
6.3.3.5 Non-defining participants 271
6.4 Discussion of Factors that Impact the Reception of Most Important Water-Based Ecosystem Services 275
6.4.1 Ecosystem services that are ‘most important’ 276
6.4.2 Perceptions related to climate change as a threat to ‘most important’ water-based ecosystem services 278
6.4.2.1 Water quality 283
6.4.2.2 Household/municipal use 285
6.4.2.3 Agricultural-based ecosystem services 286
6.4.2.4 Native American cultural and spiritual values 289
6.4.2.5 Conservation of keystone (critical) species 291
6.4.2.6 Biodiversity conservation 291
6.4.2.7 Closely related regulating services 292
6.4.2.8 Hydropower; oil and natural gas extraction, and mining; and fighting forest fires 294
6.4.2.9 The remaining water-based ecosystem services 294
6.4.3 Proportion of participants that viewed the trends as threatening 296
6.4.4 Other factors that stakeholders view as potentially impacting their ‘most important’ water based-ecosystem services 301
6.4.4.1 Water quality and household/municipal use 302
6.4.4.2 Agricultural-based ecosystem services 305
6.4.4.3 Native American cultural and spiritual values 307
6.4.4.4 Conservation of keystone species and biodiversity conservation 309
6.4.4.5 Closely related regulating services 311

6.4.4.6 Hydropower; oil and natural gas extraction, and mining; and fighting forest fires 312
6.4.4.7 The remaining water-based ecosystem services 312
6.5 Summary 315

7. Discussion of Factors and Recommendations of Water-Based Ecosystem Services to be considered in Phase II of Research 317
7.1 Discussion of Factors 317
7.2 Guidelines Used for Making Recommendations for Ecosystem Services to be Considered in Phase II 323
7.2.1 Recommendations for non-market valuation 325
7.2.2 Recommendations for market valuation 333
7.3 Summary 334

8. Conclusion 335
8.1 Summary of Research Findings 335
8.2 Limitations of this Research Project 338
8.3 Call for Future Research 340

References 343

Appendix A: Breakdown of Unemployment Rates and Per Capita Income by County 359

Appendix B: Factor Analysis 361
B.1 A Basic Factor Model 361
B.2 Covariance, Mean, Variance and Standard Variables 362
B.3 Derivation of the Correlation Coefficient in Q-methodology 364
B.4 Standardization and Correlation of Variables for an R-study 368
B.5 Communality and Reliability 369
B.6 Components of Variance 372
B.7 Explained Variance 373
B.8 Centroid Factor Analysis vs. Principal Component Analysis (PCA) 374
B.9 Statistically Distinguishable Statements 377

Appendix C: The concourse of 23 water-based ecosystem services derived from the Shoshone National Forest 381

Appendix D: Focus Group Rules 383

Appendix E: Demographic Survey 385

Appendix F: Q-board with instructions given to each participant during the data collection process 387

Appendix G: Z-scores (factor scores) and corresponding ranks for each water-based ecosystem service by perspective taken from PQMethod output **389**

Appendix H: Interview Transcriptions **391**

Appendix I: Z-scores (factor scores) and corresponding ranks for each water-based ecosystem service for factors A and B (derived from null and confounding Q-sorts) taken from PQMethod output **479**

List of Figures

Figure 2.1	An ecosystem valuation framework	17
Figure 2.2	Framework for integrated assessment and valuation of ecosystem functions, goods and services	18
Figure 3.1	Map of the study area	54
Figure 3.2	Median household income – actual and estimated	63
Figure 3.3	Map of the oil and natural gas wells in the study area	66
Figure 4.1	Q-board for this study	100
Figure 4.2	Example of scree test using 7 principal components	132
Figure 6.1	Racial breakdown of participants	221
Figure 6.2	Highest level of education achieved by participants	222
Figure 6.3	Type of primary residence	223
Figure 6.4	Map of zip codes surveyed and number of participants in each zip code	224
Figure 6.5	Types of employment (past and present)	225
Figure 6.6	Types of organizations worked for or belonged to in the past or present	226
Figure 6.7	Participation in various recreational activities	227
Figure 6.8	Water sources used to facilitate workplace operations (past and present)	228
Figure 6.9	Water supplies for household use	228
Figure 6.10	Scree test applied to SNF Q-sort data	231
Figure 6.11	Factor array 1	243
Figure 6.12	Factor array 2	251
Figure 6.13	Factor array 3A	258

Figure 6.14	Factor array 3B	265
Figure 6.15	Frequency of ‘most important’ votes given by participants	277
Figure 6.16	Factor influencing water quality	303
Figure 6.17	Factors impacting the reception of agricultural ecosystem services	305
Figure B.1	Path model for a two-variable, one-common factor model	361

List of Tables

Table 2.1	Functions, goods and services of natural and semi-natural ecosystems	14
Table 2.2	Percent of populations by group	23
Table 3.1	Temperature statistics for the study area	59
Table 3.2	Contribution of water-related industries to total employment in 2010	64
Table 3.3	Angler days and expenditures for the Bighorn Basin, 2006	68
Table 4.1	Raw data matrix in Q	116
Table 4.2	Raw data matrix in R	119
Table 4.3	Original correlations (reflected) and extraction of factor A	124
Table 4.4	Relationship of factor loadings to correlation coefficients	125
Table 4.5	Starting points for factor extraction based on number of Q-sorts	133
Table 4.6	Rotated factor matrix	138
Table 4.7	Starting point for crib sheet	150
Table 5.1	Interests represented at focus groups	176
Table 5.2	Interests targeted for Q-sorting during data collection	184
Table 6.1	Q-set with water-based ecosystem services classified by function	201
Table 6.2	Interests represented during the Q-sorting process	219
Table 6.3	Layout of defining Q-sorts for a three-, four-, and five-factor solution	233
Table 6.4	Reliability scores of each factor for a three-, four-, and five-factor solution	235
Table 6.5	Distribution of pure, confounding, and null Q-sorts	238

Table 6.6	Results: Centroid approach vs. PCA	240
Table 6.7	Crib sheet for factor 1	245
Table 6.8	Crib sheet for factor 2	252
Table 6.9	Crib sheet for factor 3A	259
Table 6.10	Crib sheet for factor 3B	266
Table 6.11	Perceptions of climate change impacts on the 'most important' water-based ecosystem services	281
Table 6.12	Perceptions of the threat of climate change by factor	297
Table 7.1	Correlations between factor scores	318
Table B.4.1	Hypothetical R-Data matrix	369
Table B.5.1	Factor loadings for subject 1 and 9	371

Introduction

"*Whiskey is for drinking; water is for fighting over." –Attributed to Mark Twain but not verified.*

Water resources in the arid-western region of the United States are important to all human inhabitants of the region to some degree, whether it's for drinking and everyday use, or irrigation and hydropower. However, the stark reality is that freshwater everywhere, and especially in the West, is a scarce resource that must be managed judiciously, as the risk of misuse and a subsequent shortage is significant. In addition to pressure from human use, the availability of water resources will fluctuate alongside a changing climate. Therefore, management of freshwater resources requires that social aspects, like the cooperation of governmental organizations and private entities, are considered jointly with natural aspects such as the potential impact of a changing climate on biological and physical systems. Water management decisions on public lands can potentially impact the availability of a wide range of benefits derived from water to a wide range of stakeholders. This project aims to inform policy-makers and land managers about the range of benefits people derive from water within and flowing from the Shoshone National Forest (SNF), and the importance of those water benefits to stakeholders in northwest Wyoming. Henceforth, these water benefits will be referred to as water-based ecosystem services.

1.1 Problem Statement and Motivation for the Study

According to the IPCC (2007a, p. 30), "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level." Additionally, eleven of the twelve years from 1995-2006 ranked among the warmest twelve years recorded since 1850 (IPCC, 2007a). The IPCC (2007b, p. 81) asserted, "physical and biological systems on all continents and in most oceans are already being affected by recent climate changes, particularly regional temperature increases."

The physical and biological systems associated with water in the Northwest region of Wyoming have seen changes due to a warming climate. For example, an earlier snowmelt (Cayan et al., 2001; United States Geological Service, 2005), a longer frost-free season (Easterling, 2002), melting of glaciers (Cable et al., 2011), more wintertime precipitation in the form of rain (Knowles et al., 2006) and a changing frequency in extreme temperature and precipitation events (Gleason et al., 2008) have all been documented in this region. The implications of these changes for water-based ecosystem services are serious. For instance, earlier runoff and the loss of glaciers would result in less water available towards the end of the growing season, while at the same time, more frost-free days would lengthen the time suitable for the growth of crops, resulting in a greater need for irrigation water.

Prudent management of water resources requires an understanding of how biological and physical systems that provide the water-based ecosystem services to society are impacted by a changing climate. The Rocky Mountain Research Station recently released a report to that end, which assessed the vulnerability of biological and physical systems to climate change on the SNF (Rice et al., 2012). One goal of the report was the development of a process to assess the vulnerability of Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*), quantity of water, and selected plant species to climate change.

The vulnerability assessment by Rice et al. (2012) also outlined potential outcomes associated with climate change projections as they relate to water-based ecosystem services. However, the potential consequences of climate change to water-based ecosystem services were primarily assessed in the terms of natural-resource supply, with a secondary focus on the demand for those resources. Understanding how climate change will impact the flow of water-based ecosystem services as a result of the changing biophysical properties of an ecosystem is important. On the other hand, it is also crucial to understand societal preferences with regard to water-based ecosystem services when making land-management decisions because water transcends jurisdictional boundaries and, as a result, those water management decisions made on public land will have a widespread impact.

There is a diverse range of stakeholders and interested parties that rely on scarce water-based ecosystem services provided by the SNF. As a result, the fate of water resources within northwest Wyoming may be particularly contentious due to its potential as a source for energy extraction and agricultural production, as well as non-consumptive uses like recreation and biodiversity conservation. In the face of climate change and competing interests, land-manager expertise and opinion is necessary and valuable for making decisions regarding the management of water-based ecosystem services derived from public lands. However, due to limited management resources, a better understanding of societal preferences for water-based ecosystem services could help land managers prioritize their management issues. This could improve relations with the general public, as well as increase the socio-economic efficiency of management.

1.2 Research Objectives

The purpose of this study is to understand the importance of various water-based ecosystem services derived from the SNF, northwest Wyoming, to people who depend on the water to support their livelihoods and lifestyles. Knowing this will improve our understanding of how the well-being of people in the study area may be affected by the impact of climate change on water-based ecosystem services. There is also an interest in understanding if stakeholders view climate change as a threat to the flow of important water-based ecosystem services. Specifically this research will aim to complete the following objectives:

1. Identify the water-based ecosystem services being derived from the Shoshone National Forest;
2. Identify the stakeholders benefiting from these services;
3. Understand the relative importance of the different ecosystem services to the stakeholders; and
4. Understand how climate change and other factors (e.g. water and land management, water use patterns, population growth, wildfire, invasive species) are perceived by stakeholders to influence or threaten the quality, quantity and value of the water-based ecosystem services.

The information gathered by completing the above objectives should assist land-managers to make sound decisions about the protection and allocation of scarce water-based ecosystem services that are threatened by climate change and other drivers.

1.3 Justification

The SNF and its surrounding area are ideal for ecosystem service research for a number of reasons. Aside from being the first national forest, the SNF is also part of the Greater Yellowstone Ecosystem (GYE), which offers natural resources that are sought after for a variety of reasons (e.g. timber, tourism and recreation, oil and natural gas extraction, and aesthetics). This study focuses on water resources because it is a highly consumed resource within semi-arid northwest Wyoming, and the water-based ecosystem services in the region are recognized as being vulnerable to climate change (Rice et al., 2012).

The GYE is rich in natural resources and, consequently, there is competition between stakeholders for the use of water for a diverse range of purposes. For example, Buehrer (2011) outlined the Crow Water Rights Settlement Act of 2010, which was ratified by Crow Indian tribal members on March 19, 2011[1], and highlights the struggle of the Crow Indian Tribe to harness the potential water benefits provided by the SNF. This Act includes $460 million in federal funding for the development of both a new municipal water system and hydroelectric projects at the Yellowtail Dam. Additionally, the funding will be used for the restoration of the dilapidated irrigation system that exists on the Crow Indian Reservation. On August 30, 2012, the benefits of the Act became a reality when

[1] United States Congress passed the Act in November of 2010, but it could not be finalized until Crow citizens ratified it (Toensing, 2011), which happened in March, 2011.

the Crow Tribe and the Bureau of Reclamation signed an agreement for a $246 million contract that, over the next 10 years, will include “the planning, design and construction of a municipal, rural and industrial water system” on the Crow Indian Reservation (Gazette Staff, 2012, p. 1).

The 2010 Act also included the 1999 Crow Tribe-Montana Water Right Compact, which gives the Crow Indian Tribe the right to 500,000 acre-ft of water per year from the Bighorn River, and 150,000 acre-ft of water per year from Bighorn Lake; a third of the 150,000 acre-ft from Bighorn Lake can be used outside of the reservation. Also, the Crow Tribe has a right to an additional 150,000 acre-ft of water stored in Bighorn Lake, which can be used to supplement the right to the Bighorn River during times of shortage. The water right entitles the Crow Tribe to water that was previously unavailable, as well as the funding needed to develop infrastructure to use the newly available water. The right to a total of 800,000 acre-ft (1 acre-foot equals 325,851 gallons) of water is substantial, especially when one considers that, as of 2005, the entire state of Wyoming (population 568,158) used about 86,000 acre-ft of water to supply their domestic household needs for an entire year (Kenny et al., 2009). This Act is expected to create jobs, and boost the agricultural economy within the community. The success of these future projects depends on the availability of water coming from the SNF.

Another water-related issue within the study area is the degradation of the water supply for the town of Pavillion, which is located in close proximity to the Wind Indian Reservation. The groundwater supply for the town of Pavillion has allegedly been contaminated by hydraulic fracturing, more commonly referred to as "hydro-fracking." According to Pelzer (2012), the Environmental Protection Agency released a report in December of 2012 that linked the contaminated water supply with hydro-fracking for natural gas. As a result of the contaminated water supply, the Wyoming Department of Environmental Quality has begun the process of installing cisterns for Pavillion residents, which will be used to hold truck delivered water (Pelzer, 2012). The Wyoming State Legislature has appropriated $750,000 for the installation of the cisterns, but the cost of trucking in water on a monthly basis (estimated at about $165 per month per household) will be the responsibility of the residents (Dayton, 2012).

Prudent allocation of scarce water resources could potentially improve the relationship between federal land managers and the stakeholders being impacted by their decisions. There are relatively few studies that use stakeholder perspectives as an aid for identifying possible natural-resource values, and ecosystem-management alternatives (Stein et al., 1999; Martin et al., 2000; Ananda & Herath, 2003). Instead, most studies rely on the stakeholders to assess the values or management possibilities developed by experts, analysts, managers, or other prominent stakeholders. Manager and expert opinions about how water-based ecosystem services should be managed are important in the face of climate change and competing interests. However, given that the SNF is managed for society as a whole, social preferences should also play a role.

Jacobs (1997) made the argument that environmental decisions should be made in the public arena, because it is not simply a decision based on costs and benefits, but also a decision based on right and wrong. Many ecosystem services are public goods and the management of those goods are subject to both positive and negative externalities, something that does not hold true for private goods. Even though the economic value of aesthetics may not be obvious, "for many, nature is an unparalleled source of wonderment and inspiration, peace and beauty, fulfillment and rejuvenation" (Daily et al., 1997, p. 11). For these reasons it is important to gain the perspectives held by the full range of stakeholders, with regard to what is important, when land management decisions are being made.

The managers of the SNF are currently working toward an updated management plan, the timing of which also serves as justification for this project. In fact, the new draft management plan was published in the Federal Register on August 3, 2012, and the 90-day public comment period ended on November 1, 2012. The final results and recommendations of this research study were available around the end of October, which combined with public comments could assist in providing further information for the final draft of the management plan.

The information gathered during this project will also support planned future phases of research in the SNF, which will estimate market and non-market values of water-based ecosystem services, and utilize existing climate models to build a decision-support tool where costs and benefits of alternative climate and land management scenarios can be evaluated. The present study will aid in directing future research by providing a thorough review of climate change literature, and by improving understanding of which water-based ecosystem services are most important to stakeholders. By combining the information derived from climate modeling with knowledge about local stakeholder preferences, it will be possible to support development of management strategies that are publicly acceptable, economically justified, and environmentally sustainable in the face of a changing climate.

1.4 Layout of Thesis

This thesis is composed of eight chapters including the introduction. Chapter 2 consists of a literature review, which is focused on the concept of ecosystem services, the perceptions of the United States adult population regarding climate change, impacts of climate change on a global scale to natural resources, the concept of climate change vulnerability, and the state of climate change modeling. Chapter 3 discusses the geographical, political, social, and economic qualities of the study area, which serves as a context within which the results of the study are analyzed and interpreted. Chapter 3 also includes a discussion of climate change impacts to water resources within the study area, and the potential implications of those impacts on water-based ecosystem services.

Chapter 4 introduces Q-methodology, the method chosen for this project, along with a broad range of disciplines that have also applied Q-methodology. The majority of Chapter 4 focuses on the theory and standard procedure of Q-methodology, which will be followed by a short section on the investigator's justification for the use of Q-methodology instead of another preference elicitation method. Chapter 5 describes the application of Q-methodology to the study area for the elicitation of stakeholder preferences regarding the importance of water-based ecosystem services derived from the SNF.

Chapter 6 presents the results of the study by outlining all of the identified water-based ecosystem services being derived from the SNF, and the preferences for those ecosystem services as indicated by a broad range of stakeholders. Chapter 6 also discusses the perceptions of stakeholders related to the threat of climate change and other drivers to their most important water-based ecosystem services. Chapter 7 includes a discussion of the results, including a recommendation for water-based ecosystem services that should be included for market and non-market valuation in the next phase of research. Chapter 8 concludes the thesis.

Chapter 2

Literature Review of Ecosystem Services and Climate Change Concepts

This literature review will proceed in two parts. The first section will discuss the definition and classification of ecosystem services, as well as the types of values that comprise the total value of ecosystem services. A firm understanding of ecosystem services is essential for the completion of objectives 1, 2, and 3 outlined in Section 1.2. The second section will discuss the concept of climate change vulnerability, the broad impacts of climate change on natural resources and human systems on a global scale, and climate change modeling. The completion of objective 1 will not only rely on ecosystem service literature but also on climate change literature because identifying the full range of water-based ecosystem services derived from the Shoshone National Forest (SNF) may be facilitated by an understanding of the vulnerable water resources. In order to complete objective 4 presented in Section 1.2, as well as future phases of this project, an understanding of climate change vulnerability will be beneficial. Also, an understanding of the perspectives of American society on climate change could be helpful for interpreting the perceptions that stakeholders have about climate change within the study area. Additionally, knowledge of climate change impacts on a global scale will give context to the discussion of climate change impacts on water resources within the study area, which will be presented in Chapter 3. Since this study is part of a multi-phase project that aims to develop a decision-support tool to facilitate water resource management, a brief discussion regarding climate change modeling is also pertinent.

2.1 Ecosystem Services

In order to identify water-based ecosystem services derived from the SNF, and discuss potential threats to those services, one must adopt a definition of ecosystem services. Most ecosystem service literature differentiates between ecosystem functions, and ecosystem services. For the purpose of this study, ecosystem functions are defined as "the habitat, biological or system properties or processes of ecosystems" (Costanza et al., 1997, p. 253). In order to exhibit the link between ecosystem functions and services, this study also includes de Groot's (1992 cited in de Groot et al., 2002, p. 394) definition of ecosystem functions, which is stated as the "capacity of natural processes and components to provide goods and services that satisfy human needs." The capacity to satisfy human needs is important because ecosystem services are defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al., 1997, p. 253). Thus, "observed ecosystem functions are reconceptualized as 'ecosystem goods or services' when human values are implied" (de Groot et al., 2002, p. 395). In the context of this study, water-based ecosystem services include, but are not limited to: recreation, irrigation, hydropower, wetland nutrient sequestration, cultural and spiritual values, and drinking water.

2.1.1 Classification of ecosystem services by function

Ecosystem service literature discusses a wide range of ecosystem functions and their associated goods and services. Much of the literature also discusses different categories and groupings of ecosystem services, which may aid in the understanding of the values that humans derive from natural systems. However, most differences in categorizations are in name only, with similar concepts being used for the classification process. For example, the Millennium Ecosystem Assessment (MEA) (2003) groups ecosystem services into four different categories: provisioning services, regulating services, cultural services, and supporting services. Provisioning services refer to the products obtained from ecosystems, including raw materials, food, fresh water, natural medicines and genetic resources. Regulating services include the benefits gained from regulation processes, such as climate regulation, disease regulation, pollination, and water purification. The MEA (2003) explained cultural services as the nonmaterial benefits derived from ecosystems. Included in this category are recreation, ecotourism, spiritual and religious services, cultural heritage and inspiration. The final category is supporting services, which refers to the services needed for the production of all other ecosystem services. The MEA (2003) cited three examples of services in this category: soil formation, nutrient cycling, and primary production.

Table 2.1 from de Groot et al. (2002, p. 396-397) provides an "overview of the main functions, goods and services that can be attributed to natural ecosystems and their associated ecological structures and processes." The italicized rows in Table 2.1 highlight the four categories of ecosystem functions and services. The regulation, production, and information functions and their related ecosystem services in Table 2.1 are closely related to the MEA's (2003) concept of regulating services, provisioning services, and cultural services, respectively. The MEA's (2003) concept for supporting services is also closely related to the habitat function described by de Groot et al. (2002, p. 396) as the "basis for most other functions."

Table 2.1 Functions, goods and services of natural and semi-natural ecosystems

Functions	Ecosystem processes and components	Goods and services (examples)
Regulation Fuctions	*Maintenance of essential ecological processes and life support systems*	
1 Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	1.1 UVb-protection by O_3 (preventing disease). 1.2 Maintenance of (good) air quality. 1.3 Influence on climate (see also fuction 2.)
2 Climate regulation	Influence of land cover and boil. Mediated processes (e.g. DMS-production) on climate	Maintenance of a favorable climate (temp., precipitation, etc.) for, for example, human habitation, health, and cultivation
3 Disturbance prevention	Influence of ecosystem structure on dampening env. disturbances	3.1 Storm protection (e.g. by coral reefs). 3.2 Flood prevention (e.g. by wetlands and forests).
4 Water regulation	Role of land cover in regulating runoff & river discharge	4.1 Drainage of natural irrigation. 4.2 Medium for transport.
5 Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers)	Provision of water for consumptive use (e.g. drinking, irrigation and industrial use)
6 Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land. 6.2 Prevention of damage from erosion/siltation.
7 Soil formation	Weather of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land 7.2 Maintenance of natural productive soils
8 Nutrient regulation	Role of biota in storage and re-cycling of nutrients	Maintenance of healthy soils and productive ecosystems
9 Waste treatment	Role of vegetation & biota in removal or breakdown of xenic nutrients and compounds	9.1 Pollution control/detoxification. 9.2 Filtering of dust particles. 9.3 Abatement of noise pollution.
10 Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species 10.2 Pollination of crops
11 Biological control	Population control through trophic-dynamic relations	11.1 Control of pests and diseases 11.2 Reduction of herbivory (crop damage)
Habitat Functions	*Providing habitat (suitable living space) for wild plant and animal species*	*Maintenance of biological & genetic diversity (and thus the basis for most other functions)*
12 Refugium function	Suitable living space for wild plants and animals	Maintenance of commercially harvested species
13 Nursery function	Suitable reproduction habitat	13.1 Hunting, gathering of fish, game, fruits, etc. 13.2 Small-scale subsistence farming & aquaculture
Production Functions	*Provision of natural resources*	
14 Food	Conversion of solar into edible plants and animals	14.1 Building & Manufacturing (e.g. lumber, skins). 14.2 Fuel and energy (e.g. fuel wood, organic matter.) 14.3 Fodder and fertilizer (e.g. krill, leaves, litter).

15 Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Improve crop resistance to pathogens & pests. 15.2 Other applications (e.g. health care)
16 Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Drugs and pharmaceuticals. 16.2 Chemical models & tools. 16.3 Test- and essay organisms
17 Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	
18 Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelery, pets, worship, decoration & souvenirs (e.g. furs, feathers, ivory, orchids, butterflies, aquarium fish, shells, etc.)
Information Functions	*Providing opportunities for cognitive development*	
19 Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)
20 Recreation	Variety in landscapes with (potential recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21 Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, pointing, folklore, national symbols, architect, advertising, etc.
22 Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23 Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

Source: de Groot et al. (2002, p. 396-397).

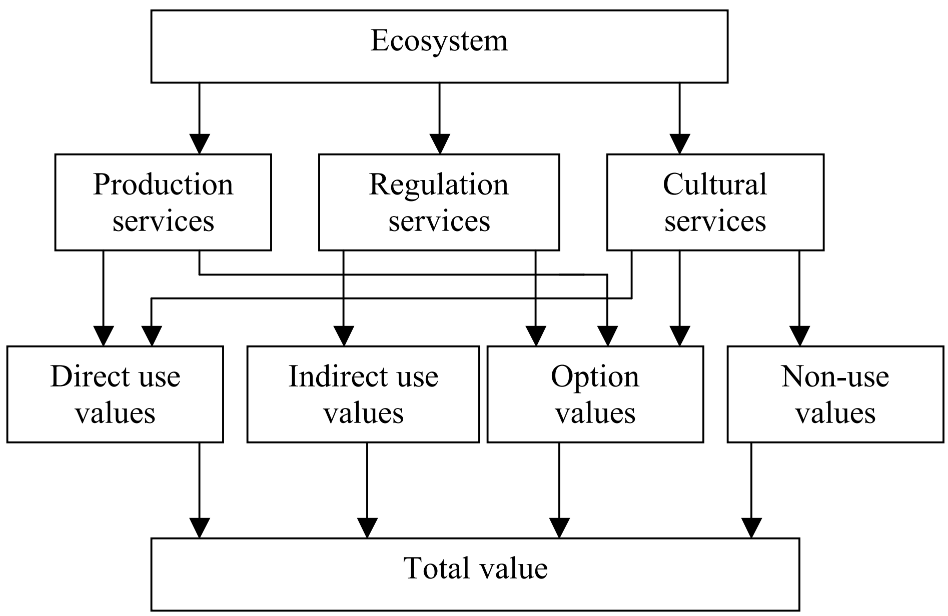
Hein et al. (2006) take a similar approach by grouping all ecosystem services into three categories: production services, regulation services, and cultural services. These categories are analogous to those developed by the MEA (2003) and de Groot et al. (2002) with one exception; the supporting services defined by MEA (2003) and the habitat functions defined by de Groot et al. (2002) are grouped by Hein et al. (2006, p. 212) into the category for cultural services, and are simply defined as, “nature and biodiversity (provision of a habitat for wild plant and animal species).”

2.1.2 Classification of ecosystem services by value

The concept of ecosystem services can encompass a variety of values, and there is inconsistency among scholars regarding the approach to classify ecosystem service values. One approach used is the arrangement of all ecosystem services into different categories based on a certain type of use. Hein et al. (2006) defined four types of use: direct use values, indirect use values, non-use values, and option values (see Figure 2.1 below). An example of a direct use value would be the fish provided to anglers by a river system, whereas, the "value of wetland nutrient sequestration in reducing eutrophication and algal blooms downstream" (Brauman et al., 2007, p. 83) would be an indirect value. According to Kolstad (2000), non-use values can be categorized into three basic types: existence values, altruistic values, and bequest values. The existence value is "the value a consumer attaches to *knowing* something exists"; the altruistic value "derives not from my own consumption but from the fact that I derive benefit when someone else gains utility"; and the bequest value is based on the benefit of knowing that future generations will gain utility (Kolstad, 2000, p. 139-140, emphasis in original). The "option value" would include the preservation of an ecosystem service for the future because there is incomplete information regarding the future need for that service (Hein et al., 2006, p. 213).

There is at times more of a discrepancy in wording than in meaning for value classification. For example, Holmlund and Hammer (1999) divided ecosystem services into two different categories: fundamental and demand-driven. Fundamental services are those that are essential for ecosystem function (i.e. nutrient cycling) and the survival of human populations, whereas demand-driven services are those that are generated by human demand (e.g. recreation), but are not necessary for human survival. Fundamental and demand-driven ecosystem services are similar to the concept of indirect and direct ecosystem services, respectively.

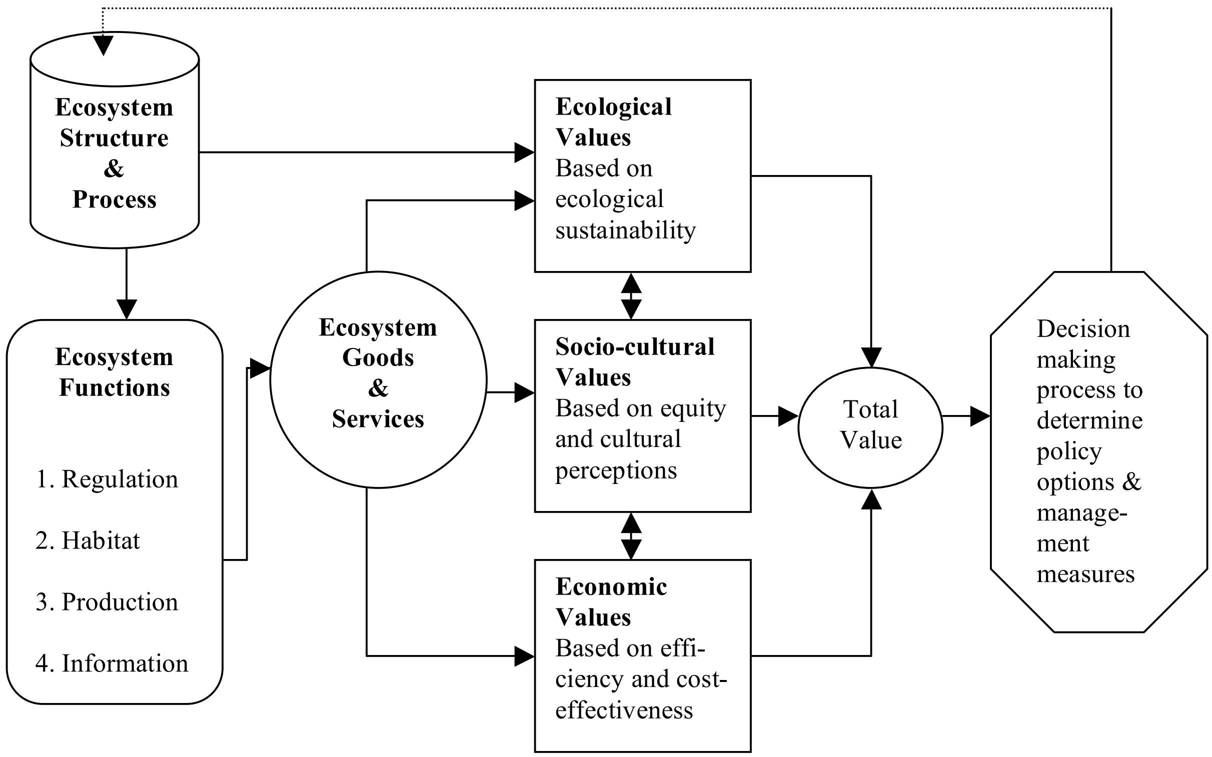
Figure 2.1 An ecosystem valuation framework



Source: Adapted from Hein et al. (2006, p. 211).

When assessing the value assigned to ecosystem services, de Groot et al. (2002) used another approach by classifying the total range of value in the following three categories: ecological value, socio-cultural value, and economic value (Figure 2.2).

Figure 2.2 Framework for integrated assessment and valuation of ecosystem functions, goods and services



Source: Adapted from de Groot et al. (2002, p. 394).

Ecological value is based on ecological sustainability, and the "continued availability of ecosystem functions" (de Groot et al., 2002, p. 402). Farber et al. (2002, p. 382) considered ecological value to also include "the 'value' of natural ecosystems and their components in terms of their contribution to human survival." Regulation ecosystem services such as carbon sequestration provided by forests, and water purification provided by wetlands may have particularly high ecological value for humans. Even though de Groot et al. (2002) did not directly draw the connection, ecological values appear to closely resemble indirect values as defined by Hein et al. (2006).

The socio-cultural value category contains social values like equity and fairness (de Groot et al., 2002). Jacobs (1997, p. 213) explained, "within their preferences, people may include concern for other people, for future generations, for distributional justice, for the intrinsic value of nature, and even concern for the common good (expressed as existence values)." Information ecosystem services such as aesthetic information, recreation, cultural and artistic inspiration, spiritual and historic information, and scientific and educational information tend to relate to socio-cultural values (de Groot et al., 2002). However, it is possible for nearly any ecosystem service to have socio-cultural value. For example, a production ecosystem service like irrigation could have socio-cultural value in a community with a deep-rooted connection to agriculture. Ecosystem services with socio-cultural value could also be direct use values, options values, and non-use values.

The economic values category pertains to the economic importance of a given ecosystem good or service, and it is typically measured in monetary terms. These values do not only include the production services (i.e. lumber, commercial fishing), but also the information services (i.e. recreation and aesthetics) (de Groot et al., 2002). Inherent in economic values is the comparison of costs and benefits and, in the case of ecosystem services, it may be the cost of maintaining an ecosystem service, compared to the cost of human production of that service (i.e. the benefit of avoided costs by protecting the environment). For example, de Groot et al. (2002) described the use of a natural water regulation service in an undeveloped watershed, compared to the avoided cost of building a water filtration plant. In this case, the avoided cost was $6 billion, which translates to an economic value of the same for the natural water regulation ecosystem service, and that does not include other services provided by the undeveloped watershed (e.g. recreation). Economic values are typically present in ecosystem services that are also direct use values.

Even though the classification approaches discussed above are different, the concept of ecosystem services is similar, mainly because they are inherently anthropocentric. The value categories are not mutually exclusive, as there is likely an overlap between categories. Also, ecosystem services are interdependent at many levels, and understanding the trade-offs among them can provide insight into the ways that damaging one service can impact the function of another service (Brauman et al., 2007).

2.1.3 The utility of employing an ecosystem services framework

In the context of this study on the SNF, adopting an ecosystem services framework and being familiar with ecosystem services classification based on ecosystem functions and value is useful because, it may help improve management by identifying both potentially overlooked ecosystem service values, and the tradeoffs between different values. According to Brauman et al. (2007, p. 84), ecosystem service frameworks can provide a "way for people to assess the impacts and trade-offs of ecosystem change, even when gains and losses accrue to different beneficiaries at disparate spatial and temporal scales." The ecosystem services framework can also "mediate resource management so that it integrates ecological, economic and social factors in an equitable way" (Jewitt, 2002, p. 889).

2.2 Climate Change

Climate change literature is abundant, and new literature is constantly emerging. Therefore, this portion of the review is not meant to be exhaustive, and will focus on literature that is pertinent to the objectives of this study. This portion of the review will be completed in four sections: The first section will discuss perceptions of American society with regard to climate change. The second section will explain the meaning of vulnerability, and its related terminology in the context of climate change. Third is a brief overview of the broad global impacts of climate change, and the fourth section will include the state of climate change modeling, and the data needs for predicting future climate change impacts within the study area.

2.2.1 Perceptions of the United States adult population regarding climate change

Objective 4 of this study, which is outlined in Section 1.2, primarily aims to understand stakeholder perspectives regarding the threat of climate change to important water-based ecosystem services. Knowledge related to the impacts of a changing climate to water resources, both globally and within the study area, will create a context in which the stakeholder perspectives about the threat of climate change can be interpreted. However, it may also be important to understand the different attitudes held by society with regard to climate change. The issue of climate change is contentious, due to both a controversy over its existence, and a lack of consensus regarding its impetus (i.e. anthropogenic vs. natural cycle). In the United States, the topic of climate change is further polarized by the different stance taken by each of the two major political parties. Maibach et al.

(2009, p. 1) stressed the need to "know thy audience" when trying to effectively communicate about the topic of climate change.

A report by Maibach et al. (2009) categorized the American public into six groups based on their perception of climate change. The six groups and their corresponding proportion of the U.S. adult population are as follows: Alarmed (18%), Concerned (33%), Cautious (19%), Disengaged (12%), Doubtful (11%), and Dismissive (7%) (Maibach et al., 2009). The report described each group in detail, explaining the beliefs related to climate change, level of involvement (i.e. the amount of time spent considering the issue and their level of knowledge about climate change), and the demographics that define each group.

Table 2.2 illustrates the proportion of the population of the United States and the Mountain region that is composed of each of the six climate change groups. The Mountain region is included in the Table because it encompasses the entire study area for this project. Also, Table 2.2 shows the proportion of both the rural and urban population in the United States that is composed of each of the six climate change groups, which may be useful for interpretation considering the large rural population in the study area. The Mountain region has a relatively higher proportion of Cautious and Dismissive residents than the United States as a whole, but a lower proportion of Alarmed, Concerned and Doubtful. The Dismissive, Doubtful, Disengaged, and Cautious populations are more likely to live in rural areas relative to the United States as a whole.

Table 2.2 Percent of populations by group

	Group					
	Alarmed	Concerned	Cautious	Disengaged	Doubtful	Dismissive
Population						
United States	18%	33%	19%	12%	11%	7%
Mountain Region*	11%	29%	26%	12%	6%	12%
Rural*	15%	31%	23%	13%	12%	8%
Urban	19%	33%	18%	12%	11%	7%

Source: Adapted from Maibach et al. (2009, p. 122 – Table 24).
Note: *Due to rounding errors, the row for the Mountain region and rural do not equal 100%.

The Alarmed population is the most convinced that global warming is happening, and they are also “the most involved with the issue and the most worried about it” (Maibach et al., 2009, p. 30). The Alarmed consider themselves to be well educated on the subject, and they perceive global warming as a very significant threat. Demographically, the Alarmed “tend to be moderate to liberal Democrats who are active in their communities” (Maibach et al., 2009, p. 35). They are more likely to be middle-aged females with higher incomes, but they are less likely to use possessions as a measure of status. They also hold strong environmental values, and are less likely to be Evangelical Christians.

The Concerned population is the largest of the six populations (33%), and they are “convinced that global warming is happening, although they are less certain than the Alarmed” (Maibach et al., 2009, p. 38). The majority of the Concerned “believe there is a scientific consensus that global warming is happening, and overwhelmingly say human activities are the cause of the problem” (Maibach et al., 2009, p. 38). The Concerned are “fairly representative of the full diversity of America in terms of gender, age, incomes, education, and ethnicities”, however, they are more likely to be moderate Democrats (Maibach et al., 2009, p. 42).

The Cautious are a group that mostly believes in the occurrence of global warming, though, their conviction is weaker than the Alarmed and the Concerned. According to Maibach et al. (2009, p. 45), "about half [of the Cautious] believe [global warming] has human causes, and over a third believe that scientists disagree a great deal on the topic. They do not perceive it as being dangerous to themselves or to other people alive today, but expect greater harm to future generations and to plant and animal species." The demographic attributes of the Cautious are generally in line with American averages, and they are "evenly divided between moderate Democrats and Republicans" (Maibach et al., 2009, p. 50).

There is a significant proportion of the U.S. adult population that is generally uninformed about the topic of climate change, and are unsure about its effects. According to Maibach et al. (2009, p. 53), the Disengaged (12%) have a "lack of knowledge or opinions about global warming – [and] as many as 100 percent of this group respond 'I don't know' to a range of questions about global warming, and most say they have given the issue little thought or attention." Demographically, the Disengaged are typically moderate Democrats who are not politically active, and they "hold egalitarian values, traditional religious beliefs, and are not strong environmentalists" (Maibach et al., 2009, p. 57).

The Doubtful population (11%) are split evenly "between those who believe that global warming is happening, those who don't, and those who don't know" (Maibach et al., 2009, p. 61). Generally, the Doubtful tend to believe that global warming is "not personally relevant, or much of a threat to people in general… also they are more likely to say that global warming is caused by natural changes in the environment" (Maibach et al., 2009, p. 61). The demographic characteristics of the Doubtful group indicate they are more likely to be older-white males, with a higher level of education and a higher level of income. Politically, the Doubtful tend to be "Republicans who have an average rate of involvement in civic activities" (Maibach et al., 2009, p. 65).

The final group is the Dismissive (7%), and they are certain that global warming is not occurring. They also believe themselves to be well informed, and they feel that global warming is not a threat. Like the Alarmed, the Dismissive population is also politically involved in the issue, but they are actively working against the policies and campaigns that are for climate change mitigation. Demographically, "the Dismissive are mostly conservative Republicans and typically male. They are politically active and hold traditional religious beliefs. They strongly endorse individualistic values, opposing any form of government intervention, and are very unlikely to be environmentalists" (Maibach et al., 2009, p. 71).

A report by Leiserowitz et al. (2011) is a continuation of the baseline report by Maibach et al. (2009), and it illustrated the change in the six different perspectives of global warming. In 2011, the six Americas are Alarmed (12% down from 18% in 2009), Concerned (27% down from 33% in 2009), Cautious (25% up from 19% in 2009), Disengaged (10% down from 12% in 2009), Doubtful (15% up from 11% in 2009), and Dismissive (10% up from 7% in 2011). Compared to the original report by Maibach et al. (2009), the report by Leiserowitz et al. (2011) does not include as much detail related to the demographic characteristics of the six groups. However, both reports do include information related to political affiliation and ideology for the six Americas, and there is little difference between the reports in political ideology for the six groups.

2.2.2 Climate change vulnerability

This project aims to understand how various stakeholders perceive climate change as a threat to their most important water-based ecosystem services, which is information that is meant to compliment the biophysical vulnerability assessment (Rice et al., 2012) recently completed by the Rocky Mountain Research Station on the Shoshone National Forest (SNF). Therefore, this section will discuss the meaning of vulnerability within the climate change realm. It may be possible to mitigate future impacts through management if the vulnerability of various natural and human systems is well understood. This section will also discuss models used to inform vulnerability assessments, and which of those models may be appropriate for the study area.

2.2.2.1 Defining vulnerability in the climate change context

Defining vulnerability within the context of climate change can be a challenge, mainly due the lack of coherence among the various schools of thought on the topic (Renaud & Perez, 2010). Adger (2006) claimed that research is often vague about whether it considers vulnerability an outcome of climate change, or as the context in which climate risks are managed. Füssel (2007, p. 155) asserted that there is "no single 'correct' or 'best' conceptualization of vulnerability that would fit all assessment contexts" and, as a result, there have been a number of competing conceptualizations of vulnerability that have emerged. This has been problematic to climate change research, because it is a field that is served by the collaboration of many scholars from a number of different backgrounds (Füssel, 2007), and competing conceptualizations can make discussion across fields difficult.

In a review of vulnerability literature, Füssel (2007) described four fundamental dimensions when assessing a vulnerable situation: the system, the attribute of concern, the hazard, and the temporal reference. The system could be a "human-environment system, a population group, an economic sector, a geographical region, or a natural system" (Füssel, 2007, p. 157). The water vulnerability index (WVI) developed by Sullivan (2011) accounted for different systems with the use of two separate indexes: one that assesses the vulnerability of the user, and one that considers the vulnerability of the resource. Füssel (2007) refers to the attribute of concern as the part of the system that is vulnerable to a hazard. In the context of this project's study area, an attribute of concern could be the viable habitat of the cutthroat trout, or the livelihood of the agricultural community. The hazard refers to the "potentially damaging influence" (Füssel, 2007, p. 157), which in the context of this study is climate change. However, it could also include the potential growth of the agricultural community and the subsequent increased consumption of water resources. The final dimension described by Füssel (2007) is the temporal reference, or the time period of interest. For this project the temporal reference could include climate change in the long-term, or simply, the present day.

Combining these four dimensions creates the following description of a vulnerable situation: "vulnerability of a system's attribute(s) of concern to a hazard (in temporal reference)" (Füssel, 2007, p. 157). Using the study area for this project as an example, one description might be as follows: "vulnerability of the agricultural community's livelihood in the study area to climate change over the next 25 years."

Füssel's fundamental dimensions concept may help in narrowing the divergence of vulnerability conceptualizations by establishing a basic framework. However, there are other vulnerability-related concepts that are integral to a thorough vulnerability assessment. For example, resource vulnerability is usually viewed as the susceptibility to be harmed, whereas resilience refers to the magnitude of disturbance that a certain system can withstand before radical change occurs (Adger, 2006). Resilience also refers to the "capacity to self-organize and the capacity for adaptation to emerging circumstances" (Adger, 2006, p. 269). Hufschmidt (2011) distinguished between adaptation and adaptive capacity, with the former referring to adjustments (purposeful or incidental) directed towards reducing potential loss in the face of a hazard. Whereas, adaptive capacity refers to the ability of a system to implement adaptations, and in many cases this refers to the barriers present in a system that prohibit such adaptations (Hufschmidt, 2011). For example, a community living in a floodplain without the means to build a dam for flood mitigation would have a lower adaptive capacity, resulting in a greater vulnerability to that specific hazard. Both adaptation and adaptive capacity are seen playing a "central role in the context of resilience" (Hufschmidt, 2011, p. 626).

Like vulnerability, the meaning of resilience can also differ among scholars. For instance, Simonovic (2010) considered resilience to be the time frame in which it takes a system to return to satisfactory conditions after a radical change has occurred. This discrepancy between the ability of a system to withstand a disturbance without significant change, versus the ability of a system to rebound after a significant change has occurred does little to obscure the overall concept of resilience, but it is still an example of the varying conceptualizations of vulnerability and its related concepts. Regardless of the definition used, resilience will differ depending on the system and the attribute of concern being assessed.

Other vulnerability related concepts are highlighted in Turner et al. (2003, p. 8074), which discussed the inefficiencies of two models that focus only on the "perturbations and stressors", or hazards. The difference being that a perturbation is "a major spike in pressure beyond the normal range of variability," and a stressor is a "continuous or slowly increasing pressure" that may be within the range of normal variability (Turner et al., 2003, p. 8074). Examples of a perturbation and stressor could be a hurricane and the changing climate, respectively.

2.2.2.2 Models for assessing vulnerability

The two models discussed by Turner et al. (2003) are the risk-hazard (RH) model, and the pressure and release (PAR) model, both of which are used to inform vulnerability assessments. The RH model aims to understand the impact of a hazard as a function of the exposure to a hazard and the sensitivity of the entity exposed (Turner et al., 2003).

The IPCC (2001, p. 987-993) defined exposure as “the nature and degree to which a system is exposed to significant climatic variations”, whereas sensitivity is defined as “the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli.” According to Turner et al. (2003), the RH model is inadequate because it does not question the ways in which the system may mitigate or exacerbate the impacts of a hazard, and only implicitly includes the concept of vulnerability in its framework. Additionally, the RH model does not account for different political, economic, and social structures that may have an influence on the impact of a hazard. The PAR model does a better job of addressing the system being impacted by including vulnerability explicitly into the framework. Turner et al. (2003, p. 8074) explained that the PAR model is primarily used for addressing social groups facing disaster, and seems to be “insufficiently comprehensive for the broader concerns of sustainability science.” Both of these models show examples of different conceptualizations of vulnerability, something that could be addressed with the use of Füssel’s (2007) framework.

Another essential element of a vulnerability analysis, according to Turner et al. (2003), is an analysis of the human-environment system. In the context of this project, the vulnerability of the resource and the vulnerability of the stakeholders are interdependent. Therefore, using a vulnerability model that considers the complex relationship between natural and human systems is essential. Metzger et al. (2005) described the vulnerability concept developed by the Advanced Terrestrial Ecosystem Analysis and Modeling (ATEAM) project. In their vulnerability concept, a “sustainable supply of ecosystem services is used as a measure of human well-being under the influence of global change threats" (Metzger et al., 2005, p. 254). The ATEAM project defined vulnerability as a function of exposure, sensitivity and adaptive capacity. Including adaptive capacity helps to fix some of the inadequacies of the RH and PAR models, particularly the lack of focus on how different systems may react differently to hazards. The vulnerability concept developed by the ATEAM project could be appropriate for future phases of this project because of its consideration of ecosystem services. The ATEAM project was developed with the idea that "people or sectors may be vulnerable to the loss of particular ecosystem services, [and] these losses can be caused by the combined effects of changes in climate, land use, and atmospheric composition" (Metzger et al., 2005, p. 254).

The concept of vulnerability should be considered when assessing the potential impacts of climate change and management decisions. Deciding on which vulnerability concept to use may be a challenge, mainly because of the competing conceptualizations present throughout the vulnerability literature. However, the concepts that include considerations regarding different systems may be the most appropriate. Füssel (2007) stressed the importance of being able to establish a definition of vulnerability that can be used across disciplines. Similarly, Metzger et al. (2005, p. 254) claimed that the approach developed by the ATEAM project "allows vulnerabilities to be compared across sectors, regions, and alternate futures."

2.2.3 Climate change impacts: A global outlook

Understanding the impacts of climate change to natural and human systems on a global scale will give context to those changes taking place within the study area. Climate change is a global phenomenon that is affecting natural systems in a variety of ways. This section will briefly discuss the impacts of a changing climate on a global level. The majority of this section will discuss the impacts to water resources, but there will also be a short discussion regarding the vast range of impacts to both natural and human systems.

According to IPCC (2007c), observed impacts of climate change on human health have already been documented, and include increases in heat-related mortality in Europe, allergenic pollen in the mid and high-latitudes of the Northern Hemisphere, and some areas have seen an increase in infectious disease vectors. Projected future impacts to human health include: "increases in malnutrition; increased deaths, diseases and injury due to extreme weather events [i.e. floods, drought, high-wind events, and heatwaves]; and increased burden of diarrhoeal diseases" (IPCC, 2007a, p. 48). On the other hand, fewer deaths related to exposure from cold are expected to occur in the future.

There have also been observed impacts on human industries. For example, agricultural and forestry management practices in the higher northern latitudes have had to change due to an earlier onset of spring and an increase in fire and pest activity (IPCC, 2007c). Future projected impacts to industries include an increase in crop productivity in mid- and high latitudes, and a decrease in crop productivity in lower latitudes. Overall, this change in crop productivity is expected to increase the global potential for food production (IPCC, 2007a). The projected increase in crop productivity is likely due to observed longer freeze-free periods in most mid- and high-latitude regions (Walther et al., 2002).

Natural systems are experiencing changes due to a warming climate as well. The IPCC (2007a) projected poleward and upward shifts in ranges in plant and animal species. There has also been a widespread change in the timing of certain life-cycle events. These changes are considered in the scientific branch known as phenology, or the "study of periodic biological phenomena and their relationship to weather and climate" (Herrod-Julius & McCarty, 2002, p. 68), and this knowledge can aid in the understanding of how climate change may impact certain natural systems. For example, Walther et al. (2002) noted the following changes in spring activities starting in the 1960s: earlier breeding or first singing of birds, earlier arrival of migrant birds, earlier appearance of butterflies, earlier choruses and spawning in amphibians, and earlier shooting and flowering of plants. It is important to note that these changes are taking place in the long-term, and that short-term changes are typically indicative of land-use changes and natural fluctuations in the abundance and distribution of species (Parmesan & Yohe, 2003).

Water-based resources have also been heavily influenced by a warming climate. The cryosphere, which is composed of mountain glaciers and ice caps, floating ice shelves and continental ice sheets, seasonal snow cover on land, frozen ground, sea ice and lake and river ice, is considered to be particularly sensitive to a changing climate. According to the IPCC (2007b, p. 86), "there is abundant evidence that the vast majority of the cryospheric components are undergoing generalized shrinkage in response to warming, with a few cases of growth which have been mainly linked to increased snowfall."

Overlapping with the shrinking cryosphere is a change in the large-scale hydrological cycle. Bates et al. (2008, p. 15) asserted that the possible impacts of climate change on the large-scale hydrological cycle include: "increasing atmospheric water vapor content; changing precipitation patterns, intensity and extremes; reduced snow cover and widespread melting of ice; and changes in soil moisture and runoff." These broad impacts may not be observed in all regions of the globe, and there is inherent uncertainty in predicting future conditions and knowing the exact contributors to the current conditions. However, despite these uncertainties, there is strong evidence that a warming climate has led to an intensification[2] of the hydrologic cycle (Huntington, 2006).

This brief overview of the impacts of a warming climate on the natural and human systems of the globe is by no means exhaustive; however, it does highlight certain impacts that have been observed and documented on a broad scale.

2.2.4 Climate change modeling

Simply observing how the warming climate is impacting natural resources does little in the short-run. However, it can help with the development of climate change models, which are designed to predict how the changing climate will affect natural resources in the future. Of course, there is a great deal of uncertainty in predicting the future in any situation, but it has not stopped us from trying in our everyday lives. The multi-billion dollar insurance industry is built around taking precautions in the face of future unknowns. We pay monthly premiums to protect ourselves from some unknown future

[2] Intensification refers to the acceleration of the water cycle, which could lead to an increase in precipitation, runoff, and extreme events like floods and tropical storms.

event with potentially negative consequences. Climate change modeling can help us decide what the future climate may look like, and the precautions we could take in the face of a changing climate. Also, constructing more accurate climate models could lead to more prudent and efficient management of natural resources in the face of the negative effects of climate change. This section will start by briefly discussing the state of global climate change modeling. Secondly will be a discussion of regional modeling, with specific reference to studies and models that may be appropriate for the study area.

2.2.4.1 Brief history of global climate models

The history of climate modeling summarized by Weart (2010) is saturated with tales of trial and error work done by brilliant scientists, and through this work the understanding of our climate has improved drastically. Emanuel (2007, p. 39) explained, "computer modeling of global climate is perhaps the most complex endeavor ever undertaken by mankind." Stute et al. (2001, p. 10529) stressed this complexity when they described the global climate as a result of "complex interactions between the atmosphere, cryosphere (ice), hydrosphere (oceans), lithosphere (land), and biosphere (life), fueled by the nonuniform spatial distributions of incoming solar radiation."

Naturally, then, there has been a parallel between a better understanding of our climate and the advancement of modeling techniques. The first few climate models developed in the 1950s and 1960s were relatively simple and, as modeling progressed, more components were considered. For instance, an early model blended land and ocean "into a single damp surface, which exchanged moisture with the air but could not take up heat"

(Weart, 2010, p. 210). Whereas, current models not only consider nuanced geographical characteristics (resolution), but they also "investigate time-dependent scenarios of climate evolution and can make use of much more complex coupled ocean-atmosphere models, sometimes even including interactive chemical or biochemical components" (Le Treut et al., 2007, p. 113). This is part of the reason that the acronym "GCM," originally defined as "Global Circulation Model," now more commonly stands for "Global Climate Model" or "Global Coupled Model" (Weart, 2010). To clarify, "Global Circulation Models" typically refer to the modeling of the atmosphere and ocean, because they simulate large-scale circulation of the atmosphere and the ocean (CCSP, 2008). As inferred above, a "Global Coupled Model" would include a simulation that considered both the atmosphere and ocean. A "Global Climate Model", however, could broadly refer to any aspect of the climate being modeled at the global scale. The aspects typically modeled are: atmosphere, ocean, land surface, or sea ice. GCMs should not be confused with integrated assessment models (IAMs), which incorporate predicted climatic conditions with both economic and social conditions. Four prominent IAMs are discussed in National Research Council (2010).

2.2.4.2 Limitations of climate modeling

Despite the improvements in modeling, there are limitations, especially when one considers that "the smallest single cell in a global model that a computer can handle, even today, is far larger than an individual cloud" (Weart, 2010, p. 210). Typically, a single cell (spatial resolution) in a GCM is 1 to 2º (1º latitude = approx. 111 km). For example, a GCM would simulate a climatic attribute (e.g. precipitation) at a point, and then move 1 to 2º to the north, south, east and west to make another prediction. This coarse resolution results in a simulation that has trouble accounting for features like coastlines and mountains. In addition to these technological constraints, there is also an inherent difficulty in predicting a chaotic system. Emanuel (2007, p. 31-32) described a chaotic system:

> The essential property of chaotic systems is that small differences tend to magnify rapidly. Think of two autumn leaves that have fallen next to each other in a turbulent brook. Imagine following them as they move downstream on their way to the sea: at first, they stay close to each other, but the eddies in the stream gradually separate them. At some point, one of the leaves may get temporarily trapped in whirlpool behind a rock while the other continues downstream. It is not hard to imagine that one of the leaves arrives at the mouth of the river days or weeks ahead of the other.

Predicting where the leaves will be within one hour may be impossible, because of what Emanuel (2007, p. 34) called "limited predictability." This is the idea that beyond a certain time prediction is impossible, and it is evident in many chaotic systems, including our oceans and atmosphere (Emanuel, 2007).

2.2.4.3 Predicting the future state of the climate

Predicting the state of the future climate requires an understanding of the drivers of a warming climate. According to the IPCC (2007a, p. 37), "changes in the atmospheric concentrations of greenhouse gases (GHGs) and aerosols, land cover and solar radiation alter the energy balance of the climate system and are drivers of climate change." There is considerable debate as to how much of the change is due to natural climate variability and anthropocentric forcings. However, GHG emissions have steadily increased since the Industrial Revolution, including about a 70% increase in annual emissions between 1970 and 2004 (National Research Council, 2010). The IPCC (2007a, p. 37, emphasis in original) stated, "there is *very high confidence* that the global average net effect of human activities since 1750 has been one of warming."

As a result of this effect, GCMs typically incorporate predicted human GHG emissions in order to understand the range of potential climate warming in the future. Assumptions must be made regarding anthropogenic GHG emissions, and the IPCC (2000) Special Report on Emission Scenarios uses criteria such as demographic, social, economic, environmental, and technological development in order to make predictions well into the future. Examples of future emissions scenarios include: a world with high population growth, slow economic growth, and modest technological advancement that yields a steady upward trend in emissions; a world with rapid economic growth, a global population that peaks mid-century, and rapid technological advancement with an equal reliance on all types of energy (both fossil fuel energy and renewable energy) that yields a mid-range increase in emissions; and a world where the global population peaks mid-century, and the economy shifts to a reliance on the service and information industries, this scenario yields a decrease in emissions from current day (IPCC, 2007a).

The uncertainty inherent in such predictions is obvious; however, the multiple scenarios developed are to be used as a tool to assist in climate change modeling, and the assessment of impacts. Weart (2010, p. 213) noted that while models "help people sort through countless ideas and possibilities, [by] offering evidence on which were most plausible", they do not pretend to predict the exact state of the future climate. Also, there is no likelihood attached to any particular scenario developed by the IPCC. Despite the uncertainty, all current climate models predict greater warming to come in the future (Weart, 2010).

2.2.4.4 Regional and local climate models

Up to this point, the climate change modeling discussion has been based around global models, as opposed to regional or local models. The remainder of this section will discuss regional modeling, and the input data needed to utilize those models. Even though the process of developing regional models (downscaling) can be quite complex, and a thorough discussion of the process is beyond the scope of this project phase. A brief review of downscaling methods can highlight the purposes of downscaling, along with the strengths and weaknesses of the resulting models.

Typically, a regional or local climate model will be a downscaled version of a global model (Pierce et al., 2009), with the intention of enhancing spatial and temporal resolution on the regions of interest. Wilby and Wigly (1997, p. 532) noted that, "fundamental to the approach is the assumption that relationships can be established between atmospheric processes occurring at disparate temporal and/or spatial scales." Downscaling methods can generally be divided into two categories: dynamical (numerical) downscaling, and statistical (empirical) downscaling.

Dynamical downscaling methods are driven by the output from GCMs at its lateral boundaries. According to CCSP (2008), the better representation of physical processes (resolution) through dynamical modeling can often times improve the physical realism of a regional simulation. The most popular dynamical downscaling method used is the nested regional climate model (RCM) (Denis et al., 2003), which is also known as a limited area model (LAM). The nested regional modeling technique can produce multi-decadal simulations and "describe climate feedback mechanisms which act at the regional scale" (Varis et al., 2004).

Another dynamical downscaling method is the high or variable resolution atmospheric GCM (AGCM). These are global simulations with spatial resolution varying horizontally, meaning that there is the ability to focus in on one or more regions (CCSP, 2008). Like GCMs, the AGCMs are computationally demanding and may have significant underlying errors (Varis et al., 2004). However, the main advantage of high and variable AGCMs, according to Christensen et al. (2001), is that the resulting simulations are globally consistent (cited in Varis et al., 2004).

The impact of the mountains and shorelines on the climate that is obscured by the coarse spatial resolution of the GCM will become apparent in a RCM or a high/variable resolution AGCM. By downscaling, these models can operate at a spatial resolution as fine as a few kilometers. Also, a higher spatial resolution will improve temporal resolution because "higher resolution requires shorter time steps for numerical stability and accuracy" (CCSP, 2008, p. 32). For instance, a regional climate model may simulate the attribute being modeled every 30 minutes, as opposed to a simulation every 6 hours by a GCM. In addition to finer-scale attributes, regional models are not "computationally prohibitive" to run for long climate simulations with high resolution because, unlike GCMs, they do not have to be "integrated with a domain covering the entire Earth" (Denis et al., 2003, p. 107). *Computationally prohibitive* is a relative term, however, because dynamical downscaling techniques require much more computer power than statistical downscaling methods.

Statistical downscaling "combines information about large-scale climatic changes with small scale physiographic details (e.g. topography)" (Varis et al., 2004, p. 329). This method aims to find statistical relationships linking results from GCMs with observations at the regional or local level. Statistical downscaling techniques can generally be put into three categories: weather generators, weather typing schemes, and transfer functions (Varis et al., 2004). Unlike GCMs and RCMs that rely on the circulation patterns of the climate for prediction, weather generators statistically produce results that are conditional on the sequence of weather variables. Varis et al. (2004, p. 329) concisely stated that weather generators "provide synthetic weather records (daily precipitation) by statistical models of observed sequences of weather variables." For example, Richardson's (1981) weather generator model is commonly used for climate impact studies, which simulated daily time-series of precipitation amount, maximum and minimum temperature and solar radiation for the present climate; and the precipitation occurrence and amount for each successive day are governed by the outcomes of the previous day (cited in Wilby & Wigley, 1997).

Another statistical downscaling method is the weather typing scheme, which develops statistical “relationships between atmospheric circulation types and local weather” (Varis et al., 2004, p. 329). These relationships are developed using observed data from weather stations, or through averaging meteorological data from a specific region.

The third category of statistical downscaling techniques is transfer functions, or regression methods. Regression methods are among the earliest of downscaling approaches, and generally involves establishing linear or nonlinear relationships between subgrid-scale parameters and predictor variables derived from coarse resolution scale (Wilby & Wigley, 1997).

There are a number of advantages and disadvantages regarding the two different categories of downscaling techniques. According to von Storch et al. (2000) the following are advantages of statistical downscaling when compared to dynamical downscaling approaches: “they are (1) based on standard and accepted statistical procedures, (2) computationally inexpensive, (3) may flexibly be crafted for specific purposes, (4) able to directly incorporate the observational record of the region” (cited in Xu et al., 2005, p. 794). The following disadvantages of statistical downscaling are documented in Goodess et al. (2001): “they (1) assume that predictor/predictand relationships will be unchanged in the future, (2) require long/reliable observed data series, (3) are affected by biases in the underlying GCM” (cited in Xu et al., 2005, p. 794).

The third disadvantage mentioned also applies to dynamical downscaling approaches, because the data used at the lateral boundaries of an RCM are taken directly from the chosen GCM. Many regional modeling techniques will average the outputs from global models that contain the pertinent data, however, this method "weights models that do a poor job simulating the region of interest equally with those that do a good job (Pierce et al., 2009, p. 8441). The consequences of this approach can be large when considering the inaccuracies of some GCMs. For example, Xu et al. (2005) discussed the third generation GCM of the Canadian Center for Climate Modeling and Analysis, and noted that of the 23 major river basins modeled for streamflow, only 4 were within 20% of the observed estimates.

2.2.4.5 Potential modeling approaches for a study focused on water resources

Xu et al. (2005) noted that there is a wide range of downscaling techniques, and each method has strengths and weaknesses. As a result, there is no universal method that works for all situations. Therefore, different models and downscaling techniques may be more effective depending on the facet of the climate being modeled. For example, later phases of this project will be interested in modeling the impact of climate change on water resources in the study area. One such potential impact as discussed above is the occurrence of extreme events. A study done by Diffenbaugh et al. (2005) used a RCM to predict the potential changes in extreme temperature and precipitation events in the contiguous United States. This seems appropriate considering that RCMs appear to "perform well for domains roughly the size of the contiguous United States" (CCSP, 2008, p. 33).

However, for our purposes it may be more appropriate to use a variable resolution AGCM because of the ability to focus on one region while not losing the consistency at the global scale. Planton et al. (2008) discussed the expected changes in extreme events due to climate change, and the methods used to downscale GCMs, specifically the atmosphere-ocean general circulation models (AOGCM). Planton et al. (2008, p. 573) had difficulty deciding whether dynamical downscaling methods are preferable to statistical methods, which was evident when they stated, “dynamical downscaling and statistical downscaling often give similar results when RCM are corrected and the statistical method has a good performance on present climate conditions.” As a result, Planton et al. (2008) asserted that the main source of uncertainty in predicting future extreme events lies not in the downscaling approach, but in the choice of GCM, and emission scenario, as well as the internal climate variability.

2.2.4.6 Relevant data inputs for modeling the impact of climate change on study area water resources

Given the importance of glacial melt for late summer stream flows in the study area, modeling glacial melt may be necessary for future phases of this project. Up to date data regarding the changing mass of glaciers and their contribution to streamflow within the study area will be helpful, which is provided by Cheesbrough et al. (2009), and Cable et al. (2011). According to Cheesbrough et al. (2009) there was a 25% decrease in Wind River Range glacial mass between 1985 and 2005. Cable et al. (2011) discussed the contribution of glacial meltwater during different points during the summer of 2007 and 2008. They assert that up to 70% of streamflow in the Wind River Range was contributed by glacial melt during 2007 between Julian days 181-287 (June 30-October 14). The Water flow and balance Simulation Model (WaSIM-ETH) described by Verbunt et al. (2003, p. 37) could be appropriate for this project, because it is a model that "simulates hydrological processes of river basins and contains modules for snow and glacier melt."

Data related to streamflow and precipitation will be integral to modeling purposes as well, mainly because of the implications that streamflow and precipitation have on various ecosystem services. Streamflow and precipitation modeling (Jain et al., 2002; Gray et al., 2004; Watson et al., 2009) through tree-ring studies can develop reconstructions of past climatic conditions. For example, Gray et al. (2004) noted that the magnitude of the worst single-year drought in the Bighorn Basin during the 20th century was likely not unprecedented. Their reconstruction dating back to 1250 A.D. indicated numerous drought events of equal or greater magnitude than recent events, with the 20th century containing only 2 of the 37 most severe drought years. Similarly, Watson et al. (2009) reconstructed streamflows for the headwaters of the Wind River, and their findings indicated that observed low-flow years during the gage record are also not unprecedented, with one reconstructed ten-year period (1566-1576) displaying below-average flows. Even though tree-ring reconstructions do not model future events, they are valuable in providing insight into the range of natural variability, both in precipitation and streamflow (Watson et al., 2009). Also, when used in conjunction with model simulations and instrumental records, tree-ring studies can provide "an improved basis for decision support systems and a foundation for understanding future water availability" (Watson et al., 2009, p. 235).

Modeling future streamflows and precipitation will be valuable for assessing resource vulnerability and projected water availability. The variable infiltration capacity (VIC) model can be used for predicting the impact of a warming climate on various hydrologic cycles. Wegner et al. (2010, p. 6) used the VIC model to predict streamflows in a number of locations throughout the western United States, which "produced hydrographs that were often a good fit to observed data." The VIC model seems to be a good fit for predicting future stream flows, however, certain stream qualities can skew data. For example, Wegner et al. (2010) found that one stream had a large influx of ground water leading to an underestimated flow. While another stream passed over fractured basalt resulting in a loss of water, and an overestimation of future stream flows. Therefore, the VIC model should be used with caution, but according to Wegner et al. (2010) the VIC model is superior to regression models because of its ability to adjust to hydrologic changes. Another model that predicts precipitation and runoff is discussed by Simonovic (2010), and is designed for use on a watershed scale. The Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) not only simulates the natural conditions present in a river basin, but it also accounts for human-made conditions like water control structures.

The models discussed above may be appropriate for use in the study area for this project. The data needed to utilize these models must be obtained through the downscaling of

GCMs, which requires the use of a downscaling technique. Varis et al. (2004) explained that it is important to use as many GCM scenarios as possible when evaluating climate change impacts on water resources, because it is nearly impossible to draw conclusions based on one or two GCM scenarios. Certain aspects potentially being modeled in future phases of research, such as precipitation, streamflow, temperature, and glacial mass, may be successfully represented through statistical downscaling methods because of the quality observational data available in the study area. Modeling extreme events may be best served through a dynamical downscaling method for the opposite reason. According to Kilsby (1999, cited in Varis et al., 2004, p. 333), the following information to be modeled can be helpful for an impact assessment in water resource management and the design of water resources systems:

- Mean river flow
- Mean groundwater recharge
- Mean seasonal (or monthly) variation in river flow
- Seasonal variation in groundwater recharge
- Q95 of river flow (5 percentile flow)
- Flow-duration curves of river flow
- Run-sums (volumes available to reservoir in certain time periods),
- Snowmelt supplied river flows, requiring joint temperature/precipitation information
- Mean annual flood
- T-year flood (e.g., 100 year return period)
- T-year floods with joint probability of snowmelt and rainfall

- Reliable yields for river of groundwater resource

Varis et al. (2004) claimed that the first four quantities listed above could be obtained using the output of GCMs as input for hydrologic models, without much downscaling. The remaining quantities listed are more problematic to determine without more sophisticated downscaling techniques (Varis et al., 2004).

Even as downscaling techniques advance, there will still be a need for quality observational data for the verification of models, and as direct input for statistical downscaling techniques. Quality observational data will not eliminate the uncertainty of modeling, but it will more likely assuage it. The study area for this project has snowpack, streamflow, temperature, glacial mass change, and precipitation data dating back many years, but the quality and quantity of such data can always be improved. For example, Hamlet et al. (2005) suggests that snowpack data could be improved in areas that lack observational sites, as is the case in many high elevation areas. And as data and models improve, their use in future planning may become more widespread.

2.3 Summary

Completion of the objectives outlined in Section 1.2 required that the researcher have extensive knowledge related to both ecosystem services and climate change concepts. Understanding the importance assigned to various water-based ecosystem services by stakeholders is facilitated by knowledge of the function and value frameworks used to classify ecosystem services. There were a few different classification frameworks by function discussed in Section 2.1.1, but all three addressed the difference between those ecosystem services that maintain ecological processes (e.g. water regulation), provide natural products to humans (e.g. timber), and provide the opportunity to support important aspects of culture (e.g. recreation and spiritual values). The classification frameworks by value discussed in Section 2.1.2 mainly distinguished between use values, both direct and indirect, and non-use values.

Also, gathering the perceptions of stakeholders regarding the threat of climate change, and other drivers, to water-based ecosystem services required that global climate change trends and climate change vulnerability concepts be known. There is a wide range of global impacts from climate change, three of which are widespread melting of ice, a shift in the timing of certain life cycles, and impacts to some aspects of human health. The concept of resource vulnerability to climate change varies across disciplines, but it is generally considered to be a function of some combination of resource exposure, sensitivity, resilience, and adaptive capacity.

Lastly, the basics of climate change modeling are included in this literature review because future phases of research will develop a decision-support tool to assist land managers, and climate change modeling will be integral to the development of that tool. Climate change modeling is a complex endeavor that is inherently uncertain. However, advances in technology and modeling techniques have increased the accuracy of models by allowing for a greater number of variables, and their complex interactions, to be used as data inputs. Despite these advances, there are still certain aspects of climate change modeling that are problematic, such as downscaling from a global model to a regional model, and dealing with topographic features like mountains and coastlines.

Chapter 3

Research Setting

Identification of water-based ecosystem services derived from the Shoshone National Forest, and the stakeholders that value those services, was facilitated by a firm understanding of the study area. Understanding of the geographic, economic, and social qualities of the study area increased the likelihood that a broad spectrum of stakeholders was included in the exercise used to measure stakeholder preference for the full range of water-based ecosystem provided by the SNF. In addition, the aforementioned attributes of the study area are the context in which the results of the study are analyzed and interpreted, which adds nuance to the data and final discussion. Understanding societal perspectives regarding the impacts of a changing climate on water-based ecosystem services is an objective of this study, and its completion was facilitated by an understanding of climate change impacts to water-resources on a study-area scale. Therefore, this chapter will present the geographic, socioeconomic, and cultural attributes of the study area, and the observed impacts of climate change on the water-resources within the study area.

3.1 Geography of the Study Area

The research setting for this project encompasses the entire area of the Shoshone National Forest (SNF), and the surrounding communities that derive water-based ecosystem services from the Forest. This section will discuss the physical geography of the study area, which will explain the boundaries of the study area, along with its water resources, topography, vegetation and climate. Also, a brief discussion of the human geography of the study area will be included.

3.1.1 Study area boundaries

The study area is illustrated in Figure 3.1, and is located in the northwestern portion of the continental United States, exclusively in the states of Wyoming and Montana. The majority of the study area, which has an area of 11,241,416 acres (4,549,239 hectares) or 17,565 square miles (45,493 square kilometers) lies within northwestern Wyoming, with a small extension reaching into south-central Montana. The study area includes all, or part, of the following counties: Fremont, Hot Springs, Washakie, Park, Big Horn[3], Carbon, and Yellowstone.

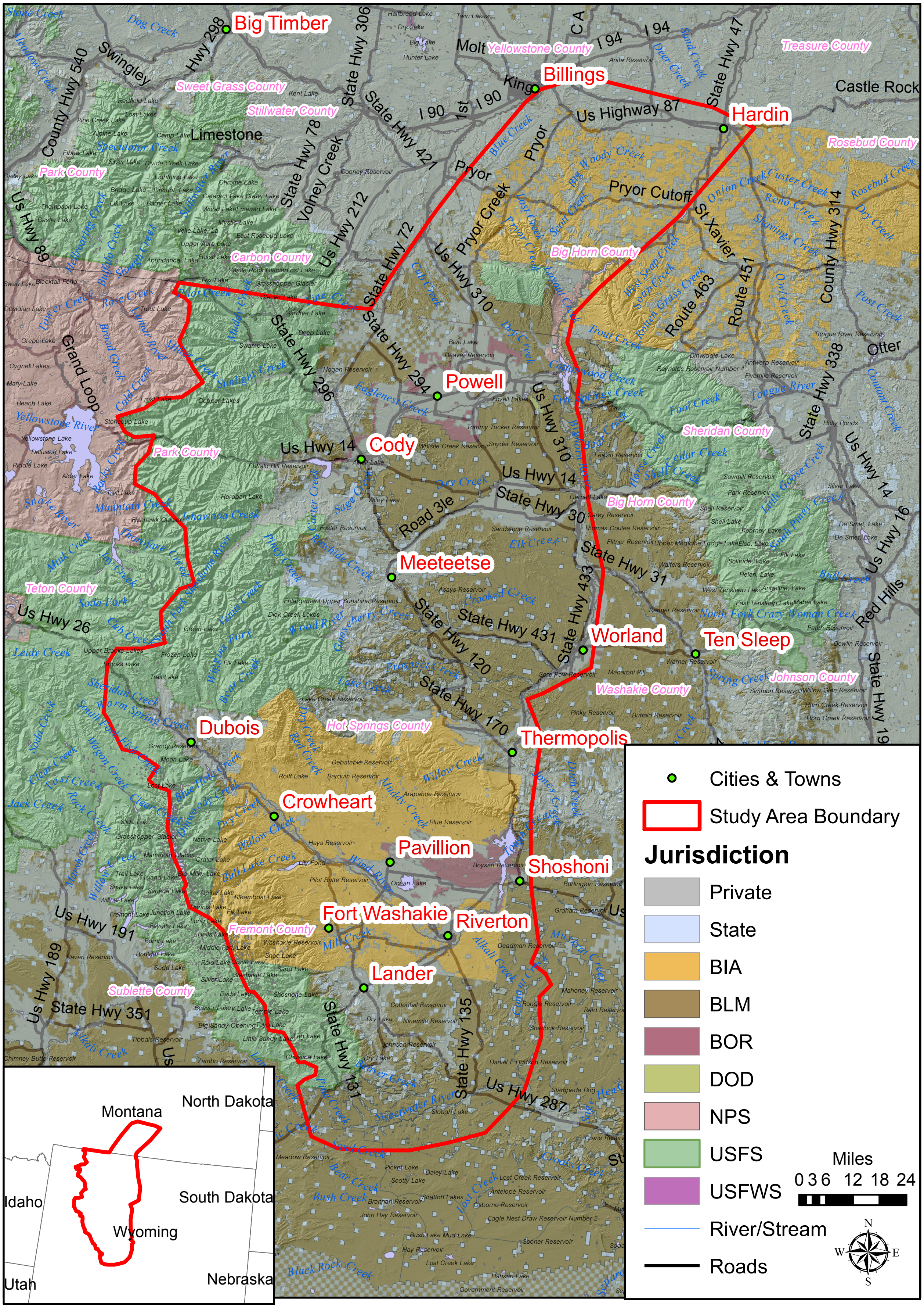
The study area includes all water within, and flowing from, the SNF and, consequently, the study area boundaries were mostly dictated by watercourses. The only exception is the western boundary of the study area, which is marked by the western edge of the SNF. Most of the western border of the SNF is traced by the continental divide and, as a result, the water stored in glaciers, high-mountain lakes, and headwater streams drain to the east into the expansive Wind-Bighorn Basin. The Wind-Bighorn Basin, hereafter referred to as the Basin, is named after the prominent Wind River Range, which is the border to the west side of the Basin, and the Bighorn Mountains, which flank the eastern side of the Basin. The Bighorn River flows north through the Basin, effectively bisecting it into a western portion and an eastern portion. The western portion of the Basin makes up most

[3] There is a Big Horn county in both Montana and Wyoming, and the study area includes part of both.

of the study area. The southern border of the study area follows the Sweetwater River for a while before extending north to the Boysen Reservoir. From there, the Bighorn River designates the eastern border until it reaches the Yellowstone River. The Clarks Fork of the Yellowstone River is used as the northwestern boundary of the study area as it exits the SNF and flows northeast before merging with the Yellowstone River.

All water that originates in the SNF eventually flows into the Missouri River, and ultimately contributes to the flow of the Mississippi River. Most of the water flowing from the SNF finds the Missouri River via the Yellowstone River, but a small number of watersheds within the southern tip of the SNF drain into the Platte River system. However, for the purposes of this project, the water-based ecosystem services derived from the Yellowstone River, Platte River, and other downstream rivers, were not considered for two reasons: (1) this project aims to understand the importance of water-based ecosystem services derived from the SNF, which becomes complicated when considering the benefits received from the Yellowstone River and Platte River because the water flowing from the SNF contributes less than half of the total flow of the Yellowstone River, and much less to the Platte River; and (2) attempting to understand the importance of water-based ecosystem services derived from these Rivers would result in a much larger study area. Expanding the study area would have required more resources, both time and financial, which were unavailable to the investigator.

Figure 3.1 Map of the study area



3.1.2 Water resources, topography and vegetation

The study area includes the western portion of the Basin, and is comprised of a wide range of water resources. The SNF contains approximately 4,063 miles of perennial streams and 310 lakes, which cover an area of 10,048 acres (USDA Forest Service, 2009a). About 1,660 of the stream miles support fisheries, and all the lakes "currently support some type of fishery" (USDA Forest Service, 2009a, p. 19). The southern end of the SNF is home to the Wind River Range, which contains a high concentration of glaciers and glacier-fed lakes. There are a number of headwater streams within the SNF, two of which are the Shoshone River and Wind[4] River. Other notable rivers within the study area include: Clarks Fork of the Yellowstone River, Greybull River, Little Wind River, Popo Agie River, Owl Creek, Beaver Creek, and Bull Lake Creek. The study area also includes several reservoirs that are supplied by runoff from the SNF: Buffalo Bill Reservoir, Pilot Butte Reservoir, Bighorn Lake Reservoir, Boysen Reservoir, Bull Lake Reservoir, Ocean Lake and Anchor Reservoir. The watersheds to the east of the Bighorn River (eastern portion of the Basin) are not included in the study area, because the water flows from the Bighorn National Forest, which is not within the scope of this study.

The topography within the study area ranges from rugged high elevation mountains to sagebrush flats. Within the SNF, the highest point of elevation is atop Gannett Peak at 13,804 ft (4,207 m), and the lowest elevation is at the mouth of Clarks Fork Canyon at 4,600 ft (1,402 m) (USDA Forest Service, 2009a). The majority of the study area that falls outside of the SNF is comprised of lower-elevation rolling hills. The exception to

[4] The Wind River and Bighorn River are the same river, but there is a name change that takes place at the "Wedding of the Waters," which is located at the northern end of the Wind River Canyon. The Wind River starts in the SNF and becomes the Bighorn River near Thermopolis, WY.

this is the Owl Creek Mountain Range, which resides within the Wind River Indian Reservation and runs east to west, effectively splitting the southern half of the study area into two parts. There are four other mountain ranges within the study area. Three are within the SNF, namely are the Wind River Range, the Absaroka Mountain Range, and the Beartooth Mountains, and the fourth, the Pryor Mountains, are located in the northern end of the study area partly within the Crow Indian Reservation.

The water resources and varied topography within the study area support a diverse range of vegetation. According to Rice et al. (2012, p. 29), the alpine vegetation zone (above 10,500 ft) comprises 25 percent of the SNF, which is described as "high-biodiversity areas with short growing seasons and rugged or rocky topography that hosts shrubs, grass and forb species." The alpine vegetation zone has also been characterized by alpine tundra and a lack of trees (USDA Forest Service, 2009b). Below the alpine vegetation zone is the sub-alpine vegetation zone, which is located between 9000 and 10,500 ft. The sub-alpine zone on the SNF supports a number of tree species, such as whitebark pine, subalpine fir, Engelmann spruce, and lodgepole pine (Rice et al., 2012). The montane vegetation zone can be found between 6000 and 9000 ft (Rice et al., 2012), and is characterized by Douglas fir (USDA Forest Service, 2009b).

Grasslands, which cover about 29.5 percent of the SNF acreage (721,000 acres), exist within most vegetative zones (USDA Forest Service, 2009b). High elevation alpine grasslands can be found on high elevation plateaus, with the exception of certain high-elevation areas in the southern portion of the SNF that have been "glacially scoured," resulting in inadequate soil development (USDA Forest Service, 2009b, p. 3). Middle elevation vegetative zones support grassland species like the Idaho fescue and Hall's fescue, and the lower elevations are dominated by bunchgrasses like bluebunch wheatgrass (USDA Forest Service, 2009b). Lower elevation areas outside of the SNF are sparsely populated by grasses and sagebrush; however, the riparian areas that exist within the river corridors and surrounding lakes and reservoirs are composed of lush vegetation, which includes cottonwood trees, willows and, the invasive species, Russian olive and salt cedar.

The study area also has a high concentration of peatlands, which Heidel et al. (2010, p. 1) described as "a specific type of wetland with water-saturated soils where dead, undecomposed organic material (peat) accumulates." The majority of peatlands in the study area are located in the northern part of the SNF within the Beartooth Mountains. Peatlands require a certain type of climate, which includes "cool annual temperatures, humid climates, and short growing seasons" (Heidel et al., 2010, p. 1). As a result of these required conditions, peatlands may be especially vulnerable to a changing climate, which is alarming because, "due to their limited distribution, exacting environmental conditions, and stability, peatlands can support a disproportionately high number of rare plant species and uncommon vegetation types" (Heidel et al., 2010, p. 1). For example, the Sawtooth Palsa Fen was discovered in the 1960s, and is the only palsa peatland known in the lower 48 states (Heidel et al., 2010). As of 2010, there are at least 305 peatland sites that have been identified and mapped, but only 105 of them have been inventoried (Heidel et al., 2010). Therefore, there is a chance that certain species have not been discovered.

3.1.3 Climate

The climate within the study area varies as a result of its diverse topography, but the study area can generally be described as a high-elevation semi-arid desert. According to USDA Forest Service (2009a, p. 14), the SNF has an annual precipitation that ranges from 15 to 70 inches, with the higher elevations receiving from "30 to 40 percent of their annual precipitation during the winter in the form of snow, roughly 40 percent as rain and snow in the spring, and 20 to 30 percent as rain in the summer and fall." The portion of the study area that falls outside of the SNF is at a lower elevation and, typically, receives far less precipitation. According to MWH Americas, Inc. et al. (2010, p. 16), the area in the Basin to the west of the Bighorn River that is not within the SNF can receive as little as 4.8 inches of precipitation a year, which is the result of the Basin's topography. MWH Americas, Inc. et al. (2010, p. 15) explained, "the Wind River and Absaroka Mountain Ranges block the flow of moisture from the west, while the Bighorn Mountains block the flow of moisture from the east."

Temperature patterns within the study area are also variable due to the different topography. The temperature statistics presented in Table 3.1 are taken from WRCC (2012), and are for the mean annual temperature, average minimum January temperature, and average maximum July temperature. The temperature data is presented for four different locations within the study area, and is meant to illustrate the range of temperatures that exist within the study area. The Darwin Ranch is located at an elevation of 8,160 ft (2,487 m) in the northern part of the Wind River Range. Temperature statistics for Cody, WY, which is located near the center of the study area, were recorded at 5,330 ft (1,645 m). Riverton, WY is located at an elevation of 4,950 ft (1,509 m) and is in the southern end of the study area, and the Yellowtail Dam is located at an elevation of 3,200 ft (975 m) and is in the northern portion of the study area.

Table 3.1 Temperature statistics for the study area

Location (elevation) Years of Record	Mean annual temperature	Average minimum January temperature	Average maximum July temperature
Darwin Ranch (8,160 ft) 1974-2012	31.05 ºF	-7.4 ºF	72.1 ºF
Cody, WY (5,330 ft) 1949-2012	44.55 ºF	10.9 ºF	84.6 ºF
Riverton, WY (4,950 ft) 1907-2012	43.2 ºF	0.5 ºF	88.8 ºF
Yellowtail Dam (3,200 ft) 1948-2012	50.25 ºF	16.8 ºF	90.2 ºF

Source: WRCC (2012).

3.1.4 Human geography

The study area encompasses more than 11 million acres, and about 72 percent of all of the land in the study area is under federal jurisdiction, most of which is managed by the Bureau of Land Management (BLM), United States Forest Service (USFS), and the Bureau of Indian Affairs (BIA). Other federal agencies managing land in the study area are the Bureau of Reclamation (BOR), Department of Defense (DOD), and the National Park Service (NPS). Private ownership within the study area accounts for 25 percent of all land, and the final 3 percent of land in the study area belongs to the State of Wyoming.

The relatively small amount of private land within the study area supports a small population of approximately[5] 100,326 people (United States Census Bureau, 2010). The study area is sparsely populated with less than 6 people per square mile. The major population centers in the study are Riverton, WY (10,615), Cody, WY (9,520), Lander, WY (7,487), Powell, WY (6,314), Hardin, MT (3,505) and Thermopolis, WY (3,009). There are eight counties that are completely, or partly, encompassed by the study area, but only seven of them contribute to the population of the study area. Yellowstone County, MT does not contribute any population to the total study area population, which is due to the fact that the study area was calculated by finding the incorporated places of each county that were in the study area, and there are not any incorporated places within the section of Yellowstone County within the study area. There is likely a small rural population within the section of Yellowstone County in the study area that was excluded because of the method used to calculate the population of the study area.

There are relatively large population centers outside of the study area boundaries, such as Billings, MT (105,845), Cheyenne, WY (59,466) and Laramie, WY (30,816), which were important to the data collection process. Populations within these areas can derive non-use benefits from water-based ecosystem services from the SNF (e.g. satisfaction from knowing there are glaciers within the Forest), but would only hold a stake in direct use values of water-based ecosystem services from the SNF when traveling within the study area. Gathering the perspectives of the full range of stakeholder groups required that attention be paid to populations outside of the study area, because many stakeholders may

[5] The approximate population for the study area was calculated by finding the total population for each county, which were then modified by subtracting the populations of cities and towns that were not within the study area boundaries.

travel from long distances to enjoy certain water-based ecosystem services provided by the SNF. Also, Cheyenne is the capital of Wyoming and, as a result, it is a population center where stakeholder groups like the Wyoming Department of Agriculture, Wyoming Water Development Commission and the Stock Growers Association are located. The University of Wyoming employs stakeholders as well, which is located in Laramie, WY.

3.2 Socio-economic Attributes of the Study Area

Knowing the socioeconomic makeup of a study area will aid in the understanding of various perspectives surrounding the importance of water-based ecosystem services. This section will start with a presentation of unemployment statistics for the study area relative to the state of Wyoming and the United States. There will also be a description of the contribution of water-related industries to the overall employment within the study area, and how those contributions compare to the states of Wyoming and Montana.

3.2.1 Unemployment and income statistics

Compared to the state of Wyoming, the Basin has a relatively high unemployment rate, and this is most likely due to the lack of economic diversity (Harvey Economics, 2010). Harvey Economics (2010, p. 5) explained that the Basin, "[is] more reliant on agriculture and mining than average and [has] less manufacturing. Diversity helps economies absorb economic downturns while specialization makes them vulnerable." Even though the unemployment within the study area is high relative to the rest of the State, it is still lower than the national average because of the boom within the energy industry (Harvey Economics, 2010). According to BLS (2012), the unemployment rate for June 2012 for the United States was 8.2 percent, and 5.5 percent for the state of Wyoming. The June 2012 unemployment rate for the study area was 6.44 percent.

The per capita income for 2010 for the state of Wyoming is $44,961, and is higher than the United States ($39,937), study area ($35,965), and state of Montana ($35,053) (BEA, 2010a). Both the unemployment rate and per capita income of the study area were calculated by averaging the countywide statistics for the seven counties that contribute to the total population of the study area (see Appendix A for a complete breakdown of the unemployment rates and per capita income by county). It may also be helpful to compare the income levels of the Indian Reservations in the study area and other relevant geographic locations. Therefore, Figure 3.2 illustrates the median household income for geographic locations pertinent to this study and, because recent income statistics are difficult to find for Indian Reservations, there are income statistics for 1999 and income estimates for 2010.

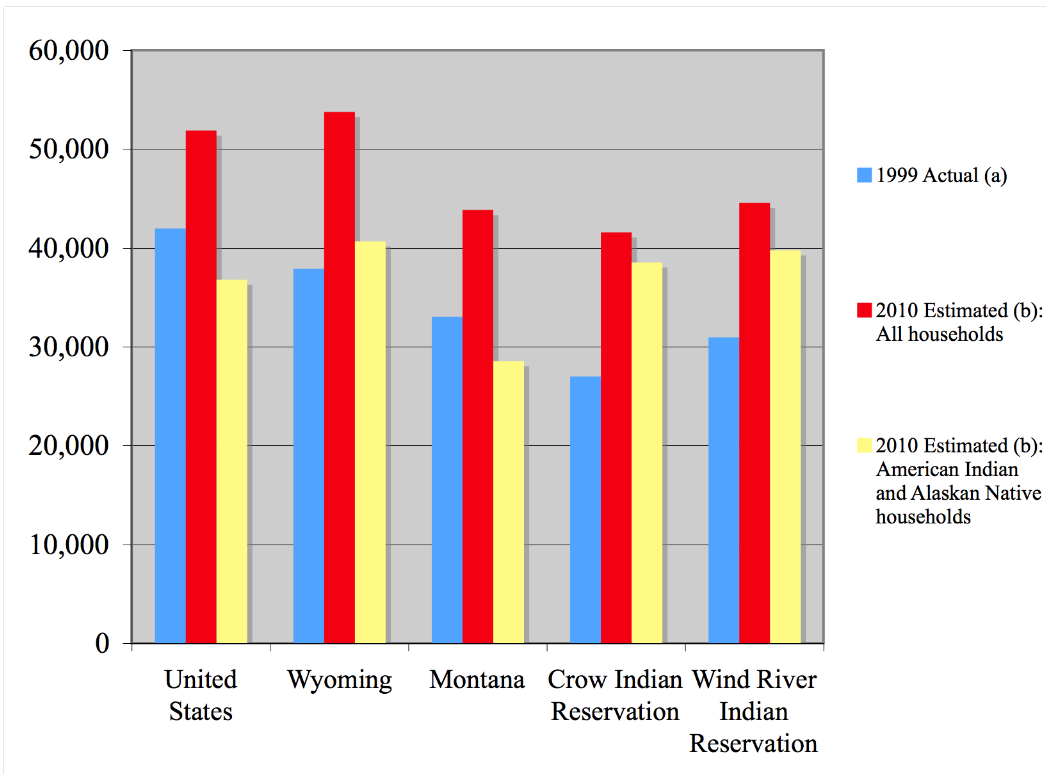
3.2.2 Contribution of water-related industries to total employment

As of 2010, the leading sector of employment, as shown in Table 3.2, within the study area that is related to water is *accommodation and food services*[6] (7.6%), which is a little less than the state of Wyoming and Montana overall. Perhaps a more telling statistic, related to the importance of water within the study area, is the large contribution of farm employment (7.0%), which is more than double the amount of employment that is

[6] *Accommodation and food services* was included as a water-related industry for two reasons: (1) the reliance of the industry on water for everyday operations; and (2) the water resources within the study area are part of the attraction for the tourist industry, which is directly supported by *accommodation and food services.*

attributed to farming within the state of Wyoming (3.2%), and significantly higher than that of the state of Montana (4.6%). The importance of mining (4.9%) within the study area for supplying jobs is also significant, especially when compared to the state of Montana (1.7%). The overall contribution of water-related industries to employment within the study area is 24.0 percent of the total 72,524 jobs.

Figure 3.2 Median household income – actual and estimated (U.S. Dollars)



Sources: a. United States Census Bureau (2000).
b. United States Census Bureau (2010).

Table 3.2 Contribution of water-related industries to total employment in 2010

	Wyoming		Montana		Study Area	
	Number of jobs	Percent of total	Number of jobs	Percent of total	Number of jobs	Percent of total
Water-related employment sectors						
Farm Employment	12,548	3.2%	28,817	4.6%	5,042	7.0%
Forestry, fishing, and related activities	2,808	0.7%	6,796	1.1%	1,123*	1.5%
Mining	30,253	7.8%	10,367	1.7%	3,537	4.9%
Manufacturing	10,629	2.8%	20,470	3.3%	2,134	2.9%
Arts, entertainment, and recreation	6,650	1.7%	18,508	3.0%	1,658	2.3%
Accommodation and food services	32,375	8.4%	49,696	8.0%	5,547	7.6%
Total for water-related sectors	95,263	24.6%	134,654	21.7%	19,041	26.2
Other industries**	290,458	75.4%	488,994	78.3%	53,481	73.8%
Total Employment	**385,721**	**100%**	**623,648**	**100%**	**72,524**	**100%**

Notes: *Exact numbers were not available, because of the need to protect confidentiality. However, the estimates were included in the total and, as a result, the investigator was able to calculate the individual estimates as well.

**Other industries not connected to water include: Utilities; construction; wholesale trade; retail trade; transportation and warehousing; information; finance and insurance; real estate and rental and leasing; professional, scientific, and technical services; management of companies and enterprises; administrative and waste management services; educational services; health care and social assistance; other services, except public administration; and government and government enterprises.

Source: BEA (2010b).

3.2.3 Economic significance of various water-related industries within the study area

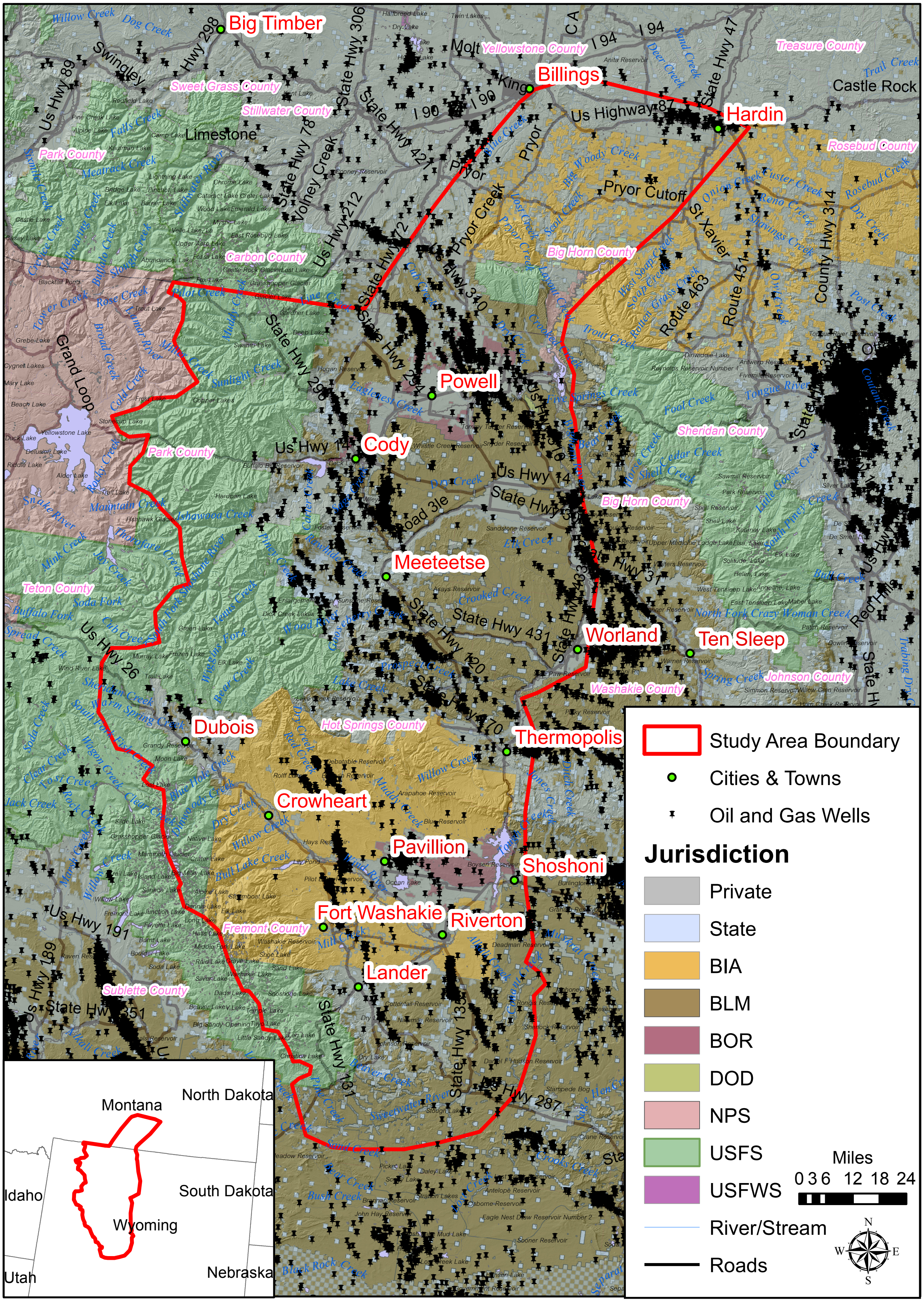
Characteristics of the Basin are described throughout this subsection because summary statistics for the study area developed for this project are not readily available. Consequently, the investigator used Basin-wide statistics as a substitute for more precise statistics of the study area. Although not perfect, the summary statistics for the Basin should be considered adequate because, despite the difference in physical geography the majority of population within the Basin also lies within the study area. According to MWH et al. (2010), the population within the basin is approximately 89,500, which is a little less than the approximate study area population of 100,326. The difference between the populations is mostly attributed to the additional population derived from the Montana portion of the study area, but there are also small towns (e.g. Ten Sleep, WY) that are included in the Basin estimate that are not included in the study area.

3.2.3.1 Oil and natural gas extraction, and mining

The importance of oil and natural gas extraction, and mining for the study area's economy is paramount. In 2007, the value of natural gas and oil production was $800 million and $500 million within the Basin, respectively (Harvey Economics, 2010). See Figure 3.3 for a map of the oil and natural gas wells in the study area. Extraction of coal, bentonite, and gypsum is also important in the Basin. In 2007, about 2.8 million tons of bentonite were mined in the Basin, which can be used for pet litter, animal feed, oilfield applications, and foundries (Harvey Economics, 2010). According to the U. S. Geological Survey (2012), a ton of bentonite was worth $52 on average in 2007, which means that 2.8 million tons of bentonite was worth about $145.6 million on the market in 2007.

Oil and natural gas extraction, and mining rely on saline groundwater, and the estimated groundwater use for all mining activities as of 2009 was 91,034 acre-feet per year (Harvey Economics, 2010). As mentioned previously, the entire state of Wyoming used about 86,000 acre-feet of water in an entire year to supply their domestic needs (Kenny et al., 2009). Oil and natural gas rely on groundwater much more heavily than other mining activities.

Figure 3.3 Map of the oil and natural gas wells in the study area



3.2.3.2 Tourism and recreational activities

Tourism and recreation is an important economic contributor to the Basin, which has had a growing impact on the economy (Harvey Economics, 2010). According to Dean Runyan Associates (2009), the total direct spending attributed to domestic and international travelers within the Basin in 2008 was $483.4 million (up from $318.5 million in 2001). That spending led to $134.4 million in direct earnings generated for the Basin in 2008 (up from $88.3 million in 2001), which supported a total of 6,320 jobs in the Basin in 2008 (up from 5,650 in 2001) (Dean Runyan Associates, 2009). Additionally, the Basin received $5.4 million in tax receipts[7] in 2008, which is a benefit that results from travelers in the area (Dean Runyan Associates, 2009).

Population centers outside of the study area (e.g. Billings, MT, Laramie, WY, and Cheyenne, WY) are sources of potential stakeholders, especially for ecosystem services related to recreation, hunting and fishing. For example, Table 3.3 shows that in 2006 there were 19,260 non-resident anglers with a combined 80,280 days of fishing in the Wind-Bighorn Basin with a total expenditure of $19,716,660.

Tourism and recreation is bolstered by YNP, which is adjacent to Park County and the northwestern portion of the study area. In 2011, YNP had a total of 3,394,326 recreational visitors, and 975,516 non-recreational[8] visitors (NPS, 2012b). YNP can be accessed through a number of different gateways and, as a result, Park County does not

[7] Tax receipts include "local option lodging and sales taxes, state sales tax and the gasoline tax" (Dean Runyan Associates, 2009, p. 25).

[8] A non-recreational visitor is defined as such if it meets any of a number of criteria, a few of which include: commuter and other through traffic, trades-people with business in the park, government personnel (other than NPS employees) with business in the park (NPS, 2012a).

see all or even most of the visitors enjoying YNP (Harvey Economics, 2010). Despite this, there is still a significant impact on the nearby economy of Park County due to YNP (Harvey Economics, 2010).

Table 3.3 Angler days and expenditures for the Bighorn Basin, 2006

	Nonresidents	Residents
Anglers	19,260	17,280
Days of fishing	80,280	224,100
Average days per angler	4	13
Total expenditures	$19,716,660	$74,149,560
Trip-related	$11,779,380	$8,129,340
Equipment and other	$7,937,280	$66,020,220
Average per angler	$1,023	$4,289
Average trip expenditure per day	$147	$36

Source: USDOI (2008, cited in Harvey Economics, 2010, p. 13).

Other tourism and recreational activities supplied by the study area are boating, whitewater rafting, hiking, camping, snowmobiling, skiing, ice climbing, and golfing. According to Harvey Economics (2010, p. 14), "although most water used for recreation is non-consumptive, water in reservoirs, lakes, rivers and streams plays an important role in attracting visitors to the region."

3.2.3.3 Agriculture

The economic contribution of agriculture within the Basin is significant and, according to USDA Census of Agriculture (2007, p. 251-253), the market value of agricultural products sold in 2007 was about $246 million. Agriculture is by far the most water-consumptive sector in the Basin. Harvey Economics (2010, p. 9) explained, "the updated irrigation mapping reports that there are 635,000 irrigated acres in the Basin. The full supply diversion requirement for current irrigated acres is 3.1 million acre-feet [92% of total diverted], or 4.96 acre-feet per acre." Crops grown in the Basin are hay for grazing and export, sugar beets for sugar, corn for silage and grain, barley for grain, and dry edible beans. The two crops that have the highest value for aggregate sales are hay and sugar beets, respectively.

Included in the agricultural market is livestock, and the economy of the Basin relies heavily on the sale of livestock, with 64% of the agricultural market value being derived from livestock sales. The majority of livestock sales are cattle. Nevertheless, between 2000 and 2008 there was a decrease of about 50,000 cattle within the Wind-Bighorn Basin, which Harvey Economics (2010) asserted was due to drought in the early part of the century, as well as a decrease in federal grazing land due to environmental and other management concerns. Sheep are also important livestock within the Basin, however, due to decreases in the price of wool, and loss to predators, the number of sheep within the area has declined (USDA NASS, 2009, cited in Harvey Economics, 2010). Other livestock in the basin include horses, hogs, hens, goats and bees, which pollinate the Basin's alfalfa. MWH Americas, Inc. et al. (2010) estimated that annual water consumption for all livestock in the Basin is about 6,370 acre-feet.

3.3 The culture of water within the study area

Interpretation and understanding of stakeholders' preferences for water-based ecosystem services derived from the SNF can be aided via knowledge of the history, and the social and cultural values related to water resources within the study area. Certain water-related current events served as part of the justification for this project, and were outlined in Section 1.3. Understanding current events regarding the water resources in the study area will also give context to the preferences for water-based ecosystem services offered by a wide range of stakeholders.

3.3.1 Brief history of water development in Wyoming and the study area

Elwood Mead, the water engineer for the territory of Wyoming, stated in 1889:

> Wyoming differs from nearly all the commonwealths of the arid region in the fact that its settlement and development is not the result of mining excitements and discoveries. The chief employment of her people has been and is yet the care and management of the grazing and farming interests. (American Heritage Center, 2000, p. 11)

Mead's statement would hold true for a number of years to follow and, even though the *chief employment* of Wyoming's people is no longer agriculture, it is still an important aspect of the economy and culture that relies heavily on water.

In 1890 the territory of Wyoming gained statehood, and all doubts that Wyoming would rely on agriculture for its maturation process were eliminated by the passage of two Federal Acts: the Carey Act of 1894, and the Newlands Reclamation Act of 1902. According to Hallberg (2008, p. 1), the Carey Act "provided federal aid to Wyoming's irrigation projects and turned over millions of acres of arid federal lands to the state for reclamation and settlement." The Carey Act gave all states the power to contract with private entities, individuals or corporations, for the development of irrigation projects, and then the states were to ensure that “the developers transferred the land to actual settlers, who would, in time, become the owners of the irrigation system” (Bonner, 2005, p. 38). The Carey Act established a system that would allow investors to build large irrigation systems on free land, and turn a profit by charging homesteaders for the use and, eventual ownership, of the irrigation systems (Bonner, 2005).

The Newlands Reclamation Act, according to Bonner (2003, p. 301), “inaugurated an ambitious program of federal dam- and canal-building aimed at opening public land in the West to homesteading through irrigation.” A product of the Newlands Reclamation Act was the governmental organization known as the United States Reclamation Service, which later became known as the United State Bureau of Reclamation (USBR). The USBR started as an agency “devoted to social settlement through irrigation,” and gradually shifted to an agency that “concentrated on dam-building and hydroelectric power generation” (Bonner, 2003, p. 303).

For Wyoming, both Acts meant a plethora of reclamation projects that greatly increased the capacity for both irrigable land and hydropower. Within the study area, the Carey Act facilitated the development of the Shoshone Land and Irrigation Company, which had three major investors, one of which was named “Buffalo” Bill Cody (Bonner, 2005). The Shoshone Land and Irrigation Company was responsible for the construction of the Cody Canal, which segregated 26,450 acres of land for irrigation though, in reality, less than a third of that acreage was productive (Bonner, 2005).

The Newlands Reclamation Act paved the way for the Shoshone Project, which was authorized in 1904 and was responsible for the eventual irrigation of nearly 90,000 acres of land in four irrigation divisions within the study area: Garland, Frannie, Willwood, and Heart Mountain (Stene, 1996). The primary goal of the Shoshone Project was irrigation, which was used mainly for the production of pasture land (Stene, 1996). As a result, the bulk of the economic worth of the agricultural market within the study area, and Wyoming, was attributed to livestock, which is a trend that continues to the present day. In addition to agricultural benefits, the Shoshone Project also provided hydropower benefits to the study area through the construction and operation of the Heart Mountain and Shoshone powerplants. The dams that were built, and the reservoirs that were developed, as a result of the Shoshone Project also created water-based recreational opportunities, however, recreation was not an objective of the Newlands Reclamation Act.

The contentious nature of water-resource allocation in the study area is inherent throughout its history, and much of the negativity stems from settlers and private citizens feeling as though their best interest was not in the mind of the policy makers. For example, the system set up by the Carey Act was not embraced by everybody. In fact, there was a significant contingent that felt “big money men, and corrupt officials such as Elwood Mead were preempting desirable locations and freezing small ranchers and farmers out of their rightful heritage” (Bonner, 2005, p. 41). There were similar negative sentiments associated with the revenue generated by the hydropower of the Shoshone Project, which resulted from the passage of the Newlands Reclamation Act. There was a dispute over hydropower revenue within the study area in the late 1920's and early 1930's, which was eventually resolved, but much political maneuvering created an inherent distrust of federal politicians within Wyoming that would not disappear. According to Bonner (2003, p. 315), "the power plant dispute shows us a bureau acting as a confident modern bureaucracy, originating policy on its own and unworried about local concerns." As a result, the tension between local Wyoming residents and federal entities grew into "entrenched opposition" and "permanent hostility" (Bonner, 2003, p. 316).

3.3.2 Native populations and water within the study area

An in-depth discussion of the history of water resources as they relate to Native populations in the study area is beyond the scope of this project, but it is important to briefly discuss Native populations and water, separate from non-Native populations, because they have a relationship with the water that is different from the non-Native populations in the study area.

The study area encompasses all of the Wind River Indian Reservation, which is the current residing place of the Eastern Shoshone Tribe and the Northern Arapaho Tribe, and most of the Crow Indian Reservation, which is the home of the Crow Indian Tribe. Water resources are important to the Native populations in the study area for many of the same reasons that they are important to the non-Native populations (e.g. irrigation, hydropower). However, the water resources within the study area are also important to Native populations for reasons that are harder to articulate. O'Gara (2000, p. 5), who chronicled the history of the battle over water between the Indians on the Wind River Reservation and the non-Indian populations that surround the Reservation, stated:

> One romantic notion about Native Americans is that they're connected to the land in some sacred sense forever inaccessible to non-Indians. More plainly, an Indian's link to the reservation is historical and indissoluble. An Indian can move from house to house, or to a faraway city, but his roots in the land of his tribe's reservation will never be cut, because the reservation is not to be bought and sold.

O'Gara (2000, p. 5) also noted that reservations are an "unhandy accommodation" set up by conquerors, who despite giving the reservations autonomous status within the U.S. Constitution, are still "entangled in the laws and lives of their non-Indian neighbors."

The investigator makes the above points because it would be a disservice to the Native populations within the study area to attempt to articulate certain values held for the water resources. The culture and traditions of the Native populations are tied to the water resources in a way that can only be conveyed by those that are part of the culture and traditions. Therefore, a discussion of the importance of cultural values held by Native populations in the study area as they relate to water will be reserved for the results chapter of this thesis, where the use of first-hand qualitative data provided by Tribal members can be employed.

3.3.3 Relationship between oil and gas extraction, and water resources in the study area

Section 1.3 on the justification of this project outlined two water-related issues within the study area, which highlight the general importance of water resources in the study area. One of those issues was related to the degradation of the water supply in Pavillion, WY, which was, at least in part, due to extraction of natural gas via hydro-fracking. This section will discuss the dichotomous viewpoint related to oil and natural gas extraction, and its impact on water resources in the study area.

As gas prices sit between $3 and $4 per gallon, the United States continues to strive for energy independence and, according to Krauss and Lipton (2012, p. 5), "the Interior Department was granted the power to issue drilling permits on millions of acres of federal lands without extensive environmental impact studies for individual projects…[and] that new power has been used at least 8,400 times, mostly in Wyoming, Utah and New Mexico." The impact of increased drilling is a stress on the aquifers, and even oil executives have acknowledged the need to reduce water consumption (Krauss and Lipton, 2012).

According to MWH Americas Inc. (2010, p. 1), water used for oil and natural gas exploration and development in the Basin is about 73,790 acre-feet per year as of 1999, which is significant considering that the entire state of Wyoming, as of 2005, used about 86,000 acre-ft of water to supply their domestic household needs for an entire year (Kenny et al., 2009). MWH Americas Inc. (2010, p. 2) noted that much of the water used for oil and natural gas "tends to be an impediment to or a by-product of the extraction process."

The *by-product of the extraction process* is commonly referred to as produced water, which is one environmental concern related to oil and natural gas extraction. According to Miller (2009, para. 1), produced water "is a briny fluid trapped in the rock of oil reservoirs. It is by far the largest toxic byproduct produced by the oil industry, and in addition to salt, it is often loaded with chemicals, residual oil and heavy metals." Produced water is usually reinjected into deep underground wells (Miller, 2009), but it is sometimes stored in effluent ponds or treated and discharged onto the landscape. Miller (2009, para. 5) noted that the water that is not reinjected into deep wells can be detrimental to the environment because it "lingers at the surface in evaporation ponds, where it can leach into surface water or become a dangerous attractant for migratory birds."

However, there is another perspective regarding produced water, which is that since it is treated to EPA standards, it can be discharged onto the landscape and used as a beneficial source of water for livestock, and it can create natural wetland habitat that would not otherwise exist. For example, Geomega Inc. (2007) developed a report for the Petroleum Association of Wyoming that outlined the benefits of produced water that is discharged to the surface to the state of Wyoming. Geomega Inc. (2007, p. ES-5) asserted that without produced water being discharged to the landscape, the Cottonwood Creek area (within the study area between Cody, WY and Thermopolis, WY) would see a 15 to 20%

loss of cattle, which would result in an estimated $2 million loss in annual livestock sales for the Bighorn Basin. Additionally, if produced water were not being discharged onto the landscape then wildlife habitat like the Loch Katrine wetland complex would not exist, which is a source of federal funding and employment in the study area (Geomega Inc., 2007).

A recent controversy over the approval of an exploratory oil-well project within the boundaries of the SNF illustrates the conflict between the mounting pressure for increased domestic production of natural energy, the benefits provided by oil and natural gas extraction, and the concern for the natural resources within the Forest. Streater (2012) explained the concerns of environmental groups with regard to the project approved by the BLM, which will be the first drilling project inside the SNF in more than 20 years. Streater (2012) cited the apprehensions of a local conservation-based non-profit with regard to the impacts to waterways, which are popular to anglers because of the diverse and plentiful fish populations. Even though the drilling project will disturb only 4.5 acres of SNF land, there is concern that the approval will lead to an increase in drilling projects on the Forest (Streater, 2012). To make matters more complicated, cooperation between the Forest Service and the BLM is required because even though the drilling is to take place on Forest Service land, it is the BLM that manages the subsurface mineral rights.

3.4 Climate Change and Water within the Study Area

Understanding various indicators of a changing climate, and finding consistency among those indicators can help us gain confidence in our assessment of the vulnerability of water resources (Huntington, 2006). The biophysical vulnerability assessment completed by the Rocky Mountain Research Station (Rice et al., 2012) documented the impacts of climate change on natural resources that have already occurred within the SNF, and made predictions about the future state of certain natural resources as well. This section will present an overview of the observed impacts of climate change on the water resources within the study area, provide a brief summary of the vulnerability assessment completed by Rice et al. (2012), and discuss the implications of a changing climate on water-based ecosystem services being derived from the SNF.

3.4.1 Observed impacts of a changing climate on water resources in the study area

A changing climate has already influenced the natural resources within the study area and, according to Rice et al. (2012), it will continue to do so in the future. However, this section will concentrate on observed trends, and not on future predictions. The following impacts have been observed in the study area, and will be discussed in order: timing of snowmelt (Cayan et al., 2001; Barnett et al., 2005; Hamlet et al., 2005; United States Geological Service, 2005; Pederson et al., 2011), earlier onset of spring (Cayan et al., 2001), longer frost-free season (Easterling, 2002), longer growing season (Feng & Hu, 2004), melting of glaciers (Marston et al., 1989; Cable et al., 2011), quantity of snowpack (Mote et al., 2005; Watson et al., 2009), the change of wintertime precipitation from snow to rain (Knowles et al., 2006; Abatzoglou, 2011) and the occurrence of extreme temperature and precipitation events (Kunkel et al., 1999; DeGaetano & Allen, 2002; Gleason et al., 2008).

3.4.1.1 Timing of snowmelt

One thoroughly studied impact on the water resources of the study area is the change in the timing of snowmelt. According to Bates et al. (2008), a number of studies have been done throughout the world with regard to potential trends in annual river runoff and discharge amounts, but the results do not clearly indicate a trend in either direction, with some studies showing declines and some studies showing increases. However, there is strong evidence that the timing of the peak runoff is happening earlier, both as a result of more precipitation coming in the form of rain instead of snow, and the earlier onset of the melting season (Bates et al., 2008). Over the last several decades in the study area the annual peak streamflow has come progressively earlier, with a center-of-volume date about 4 days earlier in the 1990s, as compared to the 1950s in the Clarks Fork of the Yellowstone River, Wyoming (United States Geological Service, 2005). Trends of up to 3 weeks earlier have been observed in the Pacific Northwest (United States Geologic Service, 2005). Pederson et al. (2011) observed an 8-day progression toward earlier melt-off since 1969 in the Northern Rocky Mountains generally.

3.4.1.2 Earlier onset of spring

Corresponding with an earlier snowmelt is an earlier onset of spring. According to Cayan et al. (2001, p. 410), "all three spring indicators—lilacs, honeysuckles, and streamflow—exhibit trends toward earlier spring time since the mid-1970's." The authors noted that the lilac and the honeysuckle were chosen as indicators in this study because their growth responds more to temperature than soil moisture and, as a result, they could attribute growth mostly to variations in temperature. The observations made by Cayan et al. (2001) took place in the western half of the United States. The honeysuckle and lilac sites are evenly spread throughout all western States, but the 110 stream gauges observed are concentrated mostly in Colorado, Wyoming, Montana, Idaho, Utah, and Washington. By observing first blooms of the aforementioned plants, the authors asserted that the bloom-date trends for the lilacs and honeysuckle are earlier by 2 days per decade, and 3.8 days per decade, respectively. Cayan et al. (2001) also noticed a trend in the spring pulse dates of about 2 days per decade earlier. The spring pulse is defined as the time, typically late spring or early summer, when "high elevation basins throughout the western United States undergo rapid transitions from dormant, low-flow stages to active, high-flow stages, as the snowpack warms and snowmelt commences (Cayan and Peterson, 1989, cited in Cayan et al., 2001).

The earlier blooming dates observed by Cayan et al. (2001) are consistent with the changes in the frost-free season observed by Easterling (2002). Easterling (2002) showed an earlier final spring frost day throughout the United States (1.3 days earlier per decade), with a change of 1.2 days earlier per decade in the region encompassing the study area for this project. Within the study area, that is a total of 6.12 days earlier for the period of 1948-1999. Easterling (2002) also accounted for a later first fall frost in the study area (0.5 days per decade). This adds up to an additional 1.7 frost-free days per decade in the study area (8.67 total for the 1948-1999 period), which implies a warmer early spring and early fall.

3.4.1.3 Frost-free days and the growing season

Directly related to frost-free days is the length of the growing season, which has a profound influence on the agricultural community and the availability of water resources. Feng and Hu (2004) discussed a number of indicators that are important to agricultural communities throughout the United States, and how each indicator changed during the period of 1951-2000. They highlighted the regional differences in agricultural indicators, and reinforced the need to be locally and regionally specific when managing for the impacts of climate change. For example, Feng and Hu (2004) state: "The increase of wet spells is particularly significant in the west-central United States from western Montana and Wyoming to Texas with an annual increase rate ranging 0.4-0.9 week per 10-yr" (p. 253). This decadal change is not observed in the eastern United States (Feng & Hu, 2004).

The onset of the growing season varies greatly with region as well. According to Feng and Hu (2004) the region that encompasses the Bighorn Basin had a growing season that started 2 days earlier per 10 years, as opposed to 1 day later per 10 years in much of Louisiana and Mississippi. A longer growing season could lead to increases in production, and it could also allow for the growth of high yield crops that require longer growing seasons in higher latitude regions (Feng & Hu, 2004). Additionally, other drivers like a growing population, and less reservoir capacity could put more stress on water resources. This could be problematic considering that the Wind-Bighorn Basin had an average annual consumptive water use for agriculture of 2.3 million acre-feet in 2000 (Jacobs & Brosz, 2000), and by 2010 that number had risen to 3.1 million acre-feet (Harvey Economics, 2010).

3.4.1.4 Melting of glaciers

Widespread melting of ice is another observed change related to a warming climate (IPCC, 2007b). Jansson et al. (2003) implicated climate change as a cause for the shrinking and potential complete melting of glaciers, resulting in a significant decrease in dry-season runoff. Even though 99.5 percent of water stored in glaciers is in the form of ice, and contained within the ice sheets of Greenland and Antarctica (Jansson et al., 2003), the smaller glaciers can be crucial for dry-season runoff in local areas. For example, Cable et al. (2011) asserted that the loss of mountain glaciers in Wyoming will exacerbate the challenges associated with drought, especially for managers and resource planners charged with the task of allocating water for agricultural and municipal use, while at the same time working to sustain the function of natural ecosystems. Cable et al. (2011) noted, “If glacial mass continues to decline as it has in the past several decades, our study suggests that streamfow may decline during critical times, such as dry years and dry periods of the year” (p. 2235).

A study by Marston et al. (1989) suggested that 8% of runoff from July to October in the Wind River is contributed by glaciers in the Wind River Range. The same study estimated that glacial contribution to Dinwoody Creek (a Wind River tributary) during

September and October is 27% and 32%, respectively. In addition to glacial melt being important for dry-season runoff, its proportion of flow during relatively dry years is also greater (Martson et al., 1989). This is consistent with a study done by Hopkinson and Young (1998) on the Bow River, Alberta, Canada, where glacial runoff contributed an average of 2% to basin flow, but in one low-flow year contributed 13% (cited in Jansson et al., 2003).

3.4.1.5 Reduced snowpack and changes in precipitation type

Reduced snowpack is another impact of a warming climate, and also varies regionally. One study by Mote et al. (2005) reported widespread declines in springtime snowpack in much of western North America (west of the Continental Divide), especially during the second half of the 20th century. Research by Pederson et al. (2011, p. 1672) suggested a small decline in snowpack in the northern Rocky Mountains from 1969-2007, with all trends "embedded within short records containing pronounced interannual variability." In contrast to the many studies done in the Pacific Northwest, it appears that the intermountain West has had a slower decline in snowpack.

The regional variation observed for reduced snowpack is also evident in studies regarding the composition of wintertime precipitation. A study by Knowles et al. (2006, p. 4546) researched the impact of a warming climate on the snowfall liquid water equivalent (SFE), which is defined as the "precipitation totals on days for which newly fallen snow was recorded." As the climate warms, the proportion of precipitation that falls as snow is expected to decrease, resulting in an increase in the proportion of precipitation that falls as rain. A study done by Abatzoglou (2011) indicates a decrease in the SFE in the Cascade and Northern Rocky regions. However, this study only included areas in the Northern Rockies that were west of 110º longitude, which is roughly representative of the western border of the study area and the Continental Divide. Therefore, these results should be applied to the study area with caution.

The study by Knowles et al. (2006) observed a larger region, including a substantial area to the east of the Continental Divide, and found that many sites in Montana, Wyoming and Colorado were among the most warmed, however, they were still colder than western sites with similar elevation, and latitude. As a result, there was little observed change in the ratio of precipitation falling as snow versus rain in the sites east of the Continental Divide, despite a significant warming trend (Knowles et al., 2006).

3.4.1.6 Extreme precipitation and temperature events

Another commonly discussed impact of climate change is the increase of extreme temperature and precipitation events, which are directly linked to drought, floods, and heatwaves. A great deal of literature regarding this subject concentrates on predicted changes in extreme events due to climate change, and the models that can be employed for these predictions. This information is pertinent to future phases of this project but, currently, a discussion concentrating on the literature that has observed changes in temperature and precipitation is needed. This literature is sparse in comparison to the predictive literature, but a few studies (Kunkel et al., 1999; DeGaetano & Allen, 2002; Gleason et al., 2008) have yielded sound results. All of these studies broadly address extremes across the contiguous United States, but it is possible to derive regional impacts from the data as well.

The study by DeGaetano and Allen (2002) observed temperature extremes across the contiguous United States during a number of periods, the longest of which was from 1900-1996. Temperature extremes were defined by those daily observations that were above the 95th percentile, and below the 5th percentile. Increasing trends with regard to the occurrence of high extremes vary regionally during the period of 1930-1996, however, during the period of 1960-1996, there are fairly widespread increasing trends across the entire country (DeGaetano & Allen, 2002). Trends regarding the minimum temperature during warm months are unclear in the study area, but trends regarding the maximum temperatures are clearly increasing during the period from 1960-1996 within the study area. Warmer maximum temperatures have also been observed in the colder months during the period of 1950-1996 throughout the country, but the trends regarding cold extremes during the wintertime months are unclear within the study area, with both increasing and decreasing trends evident.

The study done by Kunkel et al. (1999) observed short duration (1-7 days) precipitation events with a recurrence interval of one year or longer, and they documented a statistically significant upward trend of 3% per decade of extreme precipitation events throughout the United States for the period of 1931-1996. However, within the study area they documented a nominal upward trend during this same period.

The impacts discussed above indicate attributes of the study area that need to be considered when constructing a vulnerability assessment. It is also evident that there is a need for more locally specific data, because many of the impacts discussed in this section are in relation to a larger region encompassing the Rocky Mountains or the western United States. This may be especially problematic when modeling climate change, because as Wise (2010, p. 807) noted:

> Impacts are not well understood in the western Wyoming region…[being] at a latitudinal and longitudinal transition zone of precipitation patterns and teleconnection influence [(relationship between weather/climate on a global scale)] (Mock, 1996; Cayan et al., 1998). This has led to low predictive capacity for water resources in this region.

Therefore, effective modeling in future phases of research on the SNF will require regionally specific data in order to be viewed as a credible predictor of future climatic impacts on water resources. Also, discrepancies between studies may need to be addressed. For example, a study by Easterling (2002) indicated a growing season that started 1.2 days per decade (from 1948-1999) earlier in the study area. Feng and Hu (2004), however, indicated a growing season that started 2 days per decade (from 1951-2000) earlier in the study area. This is a significant difference, and it reinforces the need to be cautious with any data being used.

3.4.2 Climate change vulnerability and implications for water-based ecosystem services within the study area

A future phase of this project will consider climate change modeling, at which time detailed projections regarding the future state of the climate within the SNF will be necessary. For the purposes of this phase of the research project, however, it is sufficient to consider the potential impact of the continuation of observed climate trends on water-based ecosystem services within the study area. The trajectory of future impacts may be different due to the non-linear nature of the climate, and natural and human systems. According to the IPCC (2007a, p. 49) the "negative impacts of climate change on freshwater systems outweigh its benefits." For example, crop productivity is expected to increase slightly in areas of mid-high latitude with an increase in temperature of 1 to 3ºC. However, areas that are mainly supplied by meltwater from major mountain ranges are expected to see widespread reductions in glacial mass and snowpacks, resulting in a reduction of water availability, and hydropower potential (IPCC, 2007a).

Even though these predictions are made on a broad global scale, the literature reviewed in the previous section suggest similar predictions have been made for the study area and, if the projections hold true, then there will be potentially negative impacts on the ability of humans to receive certain water-based ecosystem services in the future. The climate change report completed by Rice et al. (2012) thoroughly documented climate change effects, with both observed trends and future projections, on the following natural ecosystems, biological processes and human systems within the SNF: water and aquatic systems, water quality, glaciers, snow, wetlands, vegetation, invasive species, fire, insects and pathogens, wildlife, fish, biochemical cycling, economies and land use. The report also discussed the current climate of the Greater Yellowstone Ecosystem (GYE) and the SNF, and future climate projections for the SNF (Rice et al., 2012).

It should be noted that there is inherent uncertainty regarding the implications of a changing climate for water-based ecosystem services, which is an acknowledgement made by Rice et al. (2012, p. 49) when they stated, "the expected changes in climate leave many questions as to how these ecosystems will adapt." Despite the uncertainty, it may be prudent to consider potential changes in climate when managing for water-based ecosystem services. The SNF has adapted to a fluctuating climate over thousands of years, and the 20th century has seen "warming of 1.8 to 3.6 ºF" (Rice et al., 2012, p. 49). According to Rice et al. (2012, p. 49), "water resources are particularly vulnerable as warmer temperatures are projected to reduce snowpacks, increase evaporation, lengthen summer seasons, and start spring runoff earlier."

3.4.2.1 Implications for fishing, hunting and recreational water-based ecosystem services

The communities (human and non-human) within the study area rely on fish populations for a number of ecosystem services. The predicted loss of trout habitat in the next century may have an adverse impact on fish-related ecosystem services. Given a composite climate scenario produced by 10 different GCMs, Wenger et al. (2011) simulated an approximate decrease of 47% in suitable trout habitat within the interior western United States by 2080. This loss is attributed to a combination of temperature, water flow regimes and biotic interactions between trout species. According to Rice et al.

(2012, p. 41), “potential consequences to ecosystem services include shifted or reduced salmonid habitat and associated species, and reduced recreational fishing opportunities for native cold water fish if salmonid habitat is reduced or degraded.”

The recreational values provided by healthy fish habitats could be impacted by a warming climate if river closures are required. Many fish species in the study area are “cold-adapted fish species” (Rice et al., 2012, p. 40), and if the water becomes too warm then management is sometimes required to close sections to fishing in order to maintain fish health. For example, Yellowstone National Park closed several miles of streams to fishing in August of 2012 because water temperatures were high enough to be considered dangerous to trout (NPS, 2012c). A loss of fishing opportunities in the study area could be devastating to an economy that already lacks diversity, especially when considering the importance of fishing as illustrated in Table 3.3 above.

A decrease in fish habitat can have an impact on other ecosystem services as well. Holmund and Hammer (1999) described a suite of fundamental and demand-derived ecosystem services that are created by fish populations. A few of those relevant to this study area that could be impacted by degraded fish habitat are: nutrient cycling, biodiversity, regulation of ecosystem resilience, linkage within aquatic ecosystems, production of food, indicators of a stressed ecosystem, aesthetic values, and cultural values.

As discussed in Section 3.2.3.2, tourism and recreation is the second most important economic industry in the study area and, according to Rice et al. (2012, p. 43), changes in climate could potentially result in "increased summer recreation and tourism activity and fewer winter recreation opportunities." Implications for hunting related ecosystem services are not as clear but, Rice et al. (2012, p. 38) asserted that certain species may seek cooler habitats in higher elevations for refuge, and there is a "potential reduction of suitable habitat and species that are unable to adapt." However, big game populations are stable or increasing in the SNF, and may have higher adaptability due to their large habitat ranges (Rice et al., 2012).

3.4.2.2 Implications for agriculture and hydropower

The implications of a longer growing season for consumptive water-based ecosystem services are significant. If the IPCC predictions hold true, and there is an increase in crop productivity, then water availability within the study area may decrease. Also exacerbating the potential loss of water availability is the loss of water due to glacial melting, and the shift of the runoff peak to earlier in the year. Barnett et al. (2005) suggested that "there is not enough reservoir storage capacity over most of the West to handle this shift in maximum runoff and so most of the 'early water' will be passed on to the oceans" (p. 305). This could be especially true if the streamflow maximum comes a month earlier by 2050, as predicted by Barnett et al. (2005). Rice et al. (2012, p. 43) suggested that climate change might reduce and create more unreliable water resources, which could potentially cause a "decrease in agricultural production and hydropower generation." The importance of agriculture to both the economy and the culture of the study area highlight the potentially serious impact that a changing climate could have on ecosystem services related to agriculture.

3.4.2.3 Implications for glacier-based services, gradual discharge of stored water and natural flood control

According to Rice et al. (2012, p. 25), “potential consequences to ecosystem services may be a temporary increase in summer stream flow followed by a reduction as glaciers disappear, terrestrial habitat that is near glaciers could be lost, and the suitability of aquatic thermal habitat near glaciers will likely shift as glaciers disappear.” Within the study area, glaciers are a reliable source of late-season melt water for the agriculture community, and are important for the regulation of stream temperature. The ecosystem services related to glaciers are likely to be negatively influenced if the climate continues to change.

Natural flood control is an ecosystem services that relies on healthy wetlands. Rice et al. (2012, p. 27) noted that there is a lack of published literature on groundwater and climate change for the SNF. However, “earlier snow melt, reduced summer precipitation, and longer growing seasons will likely cause reduced water inputs and lowering of water tables in wetlands,” which could potentially result in the loss of wetlands (Rice et al., 2012, p. 27).

As previously mentioned, there is an inherent uncertainty in projecting the impact of a changing climate on water-based ecosystem services derived from the SNF, and Rice et al. (2012) are effective in illustrating the biophysical systems that are likely to see changes in the future. This thesis project is meant to contribute to knowledge about the importance of water-based ecosystem services derived from the SNF to a broad range of stakeholders, which is information that, combined with knowledge of the vulnerability of water resources in the study area, can assist land managers in making decisions regarding water-based ecosystem services in the future.

3.5 Summary

Understanding of the geographic, economic, and social qualities of the study area is important because it will give context to the final results and interpretation. The study area is sparsely populated and abundant in natural resources, which is a quality that makes the study area particularly attractive for large scale ranching and farming and tourist industries like guiding, outfitting and guest ranching. The importance of the water resources in the study area can be highlighted by the history of water development, as well as highly visible social issues like the ongoing debate over oil and natural gas extraction. Despite the difficulty of finding locally specific literature related to climate change impacts, there is a good deal of evidence that indicates that water-resources within the study area have already seen changes due to a changing climate. As land managers move forward in the face of a changing climate it is important to understand the water resources that may be most vulnerable.

Chapter 4

Theoretical Foundation and Procedure of Q-Methodology

Q-methodology will be employed for this project in order to achieve the research objectives outlined in Section 1.2. There are three goals of this Chapter: (1) illustrate the versatility of Q-methodology; (2) explain the procedure of Q-methodology; and (3) exhibit the appropriateness of the use of Q-methodology for understanding the importance of water-based ecosystem services derived from the Shoshone National Forest (SNF). Achievement of the first goal will help to justify the use of a somewhat-obscure methodology for this project. Section one will address the first goal via a discussion of the general situations where Q-methodology is appropriate, and several disciplines that have applied Q-methodology. Completion of the second goal will exhibit the firm understanding of Q-methodology that is held by the researcher, and it will be discussed in Section 4.2. Attainment of the final goal will also justify the use of Q-methodology for this project by contrasting it to other potential methods. The third, and last, section of this Chapter will discuss other potential stakeholder elicitation methods that were not chosen for this project. Both the weaknesses of other stakeholder-elicitation methods and the strengths of Q-methodology within the context of this project will be highlighted in the final section.

4.1 General Description and Applications of Q-Methodology

Barry and Proops (1999, p. 338) defined Q-methodology as "an attempt to analyze subjectivity, in all its forms, in a structured and statistically interpretable form." Q-methodology is also meant to "identify shared views…particularly on topics over which there is much debate and contestation, such as democracy, healthcare and sustainability. It can then measure individuals' affinity with those views, as well as similarities and divergences amongst individuals" (Eden et al., 2005, p. 414).

The original application of Q-methodology was in the field of psychology, and its inventor, William Stephenson, felt that the new method would revolutionize "general and type psychology" because of its focus on the correlation of individuals, as opposed to the correlation of the characteristics of general populations (Stephenson, 1936, p. 344). Q-methodology's aim to analyze subjectivity via statistical methods has placed it in a unique position along the qualitative-quantitative methods continuum.

Due in part to the unique methodological position of Q-methodology, Stenner and Stainton Rogers (2004, p. 101) dubbed the word "qualiquantology" as a way to "express [the] discomforting hybridity" between the two traditional types of methodologies. Some of the discomfort stems from the fact that, "despite being statistically identical to many other forms of psycho*metrics,* for us, Q-methodology lays no claim to be *measuring* anything, and hence adopts a completely different relationship to questions of validity and reliability" (Stenner & Stainton Rogers, 2004, p. 102, emphasis in original). The point to be gleaned here is that Q-methodology is exploratory in nature, and it does not aim to measure the magnitude of any attitude. Instead, Q-methodology aims to understand, in a nuanced fashion, the full range of attitudes regarding some topic of interest.

The applications of Q-methodology have grown since its inception. In fact, Q-methodology has been widely adopted in the social sciences, and all but forgotten in its original field of psychology (Brown, 1997). The application of Q-methodology is, perhaps, most notable in the field of political science, which is the context of Brown's (1980) seminal work on Q-methodology. Q-methodology has also been applied in health sciences (Cross, 2005; Baker et al., 2006; Van Exel et al., 2007), research regarding the nursing profession (Barker, 2008; Akhtar-Danesh et al., 2009), feminist research (Gallivan, 1994), research on rural areas (Previte et al., 2007), tourism research (Stergiou & Airey, 2011), environmental sustainability and management (Coke & Brown, 1976; Barry & Proops, 1997; Steelman & Maguire, 1999; Bumbudsanpharoke et al., 2010; Cuppen et al., 2010; Gruber, 2011; Ray, 2011; Vugteveen et al., 2011), and human geography (Eden et al., 2005).

4.2 Procedure for Q-Methodology

This section will give a detailed description of the procedure used to complete a Q-methodology study. Much of the information that follows is taken from the in-depth descriptions of Q-methodology composed by Brown (1980), and Watts and Stenner (2012).

A Q-methodology study can typically be completed in the following six steps:

1) Creation of the concourse and Q-set
2) Creation of the Q-board
3) Recruitment of Q-sort participants

4) Completion of the Q-sort (rank ordering of the Q-set) and follow-up interview of participants
5) Data analysis
6) Interpretation and articulation of results

4.2.1 Creation of the concourse and Q-Set

The first step involves the creation of the concourse and Q-set. The concourse is typically composed of "innumerable statements of opinion" related to the topic of interest (Brown, 1980, p. 186). Originally this set of statements was called the "trait universe" (Stephenson, 1950), but later became known as the "concourse" (Stevenson, 1978). According to Brown (1993, p. 93), the statements that make up the concourse (and eventually the Q-set) have the following characteristics:

> [They are] matters of opinion only (not fact), and the fact that the Q-sorter is ranking the statements from his or her own point of view is what brings subjectivity into the picture. There is obviously no right or wrong way to provide 'my point of view' about anything -- health care, the Clarence Thomas Supreme Court nomination, the reasons why people commit suicide, why Cleveland can't seem to win the pennant, or anything else.

Brown's (1980) use of the word *innumerable* with regard to the concourse may seem like hyperbole; however, it becomes apparent that its use is appropriate when considering a topic like *why Cleveland can't seem to win the pennant*, or *why people commit suicide*. The opinions that could be offered to answer either of these questions could approach infinity. For example, the statements, "the city of Cleveland is cursed" and "Cleveland never wins the pennant" could be used as answers to the two aforementioned questions, respectively.

It is the difficult task of the researcher to distill the concourse into the Q-set, which is the set of items that are to be rank ordered by the participants during the Q-sort. According to Watts and Stenner (2005, p. 75, emphasis in original), "whatever the research question, the Q-set must always be *broadly representative* of the opinion domain at issue." Usually the Q-set is "constituted of *statements*, each making a different (but nonetheless recognizable) assertion about the appropriate subject matter" (Watts & Stenner, 2005, p. 74, emphasis in original). However, the Q-set does not need to be comprised of full statements. At its most basic level, the Q-set can be described as a "collection of 'heterogeneous items' which the participant will sort" (Watts & Stenner, 2005, p. 74). For example, Stephenson (1936) used physical objects, scents, and single-word descriptors in studies that investigated "people's *predilection for vases* (using a Q-set of vases) and the *hedonic value of certain odours* (using a Q-set of bottled fragrances). He also studied issues of *personality* by asking participants to value a population of moods (e.g., cheerful, elated, affectionate, etc.) as descriptors of their own personality" (cited in Watts & Stenner, 2005, p. 74).

Development of the Q-set is more art than science (Brown, 1980), but it generally involves a literature review, formal interviews, informal discussion, focus groups, and/or pilot tests. Brown (1980, p.188) noted, "the statement population is modeled or conceptualized theoretically," which is a task that can be aided by using the principles of variance design as described by Fisher (1960). As an example of Q-set design, Brown (1980) discussed the rationale and structuring of a Q-set for the question of what it means to "be in love." By reading through some example statements from a concourse, Brown (1980, p. 188) theorized that an observer "might speculate that some people are romantically emotional and expressive, whereas others are more realistic and down to earth, and on this basis might divide the comments, as in content analysis, between these two points." Further examination of the concourse of what it means to "be in love" indicated that both the romantic perspective and the realistic perspective can be divided into categories of "self" and "interaction," which resulted in a Q-set structure with four categories (Brown, 1980, p. 188). Those four categories were: romantic-self, romantic-interaction, realistic-self, and realistic-interaction. Brown (1980, p. 187-188) placed the following categories with the following statements:

> Romantic-Self: "It's like being reborn, like coming to life for the first time."
>
> Romantic-Interaction: "Serenity and contentment, at one with another in which time is at a standstill."
>
> Realistic-Self: "Being able to enjoy sexual integrity, with no regrets."
>
> Realistic-Interaction: "It means I can express myself freely and totally, without fear of misunderstanding or disapproval."

Brown (1980, p. 189) explained the utility of Q-set structures, or the organization of Q-set items into categories, "as a way for the investigator to be explicit about his own vantage point, but they also facilitate the selection of Q-samples [(sets)]."

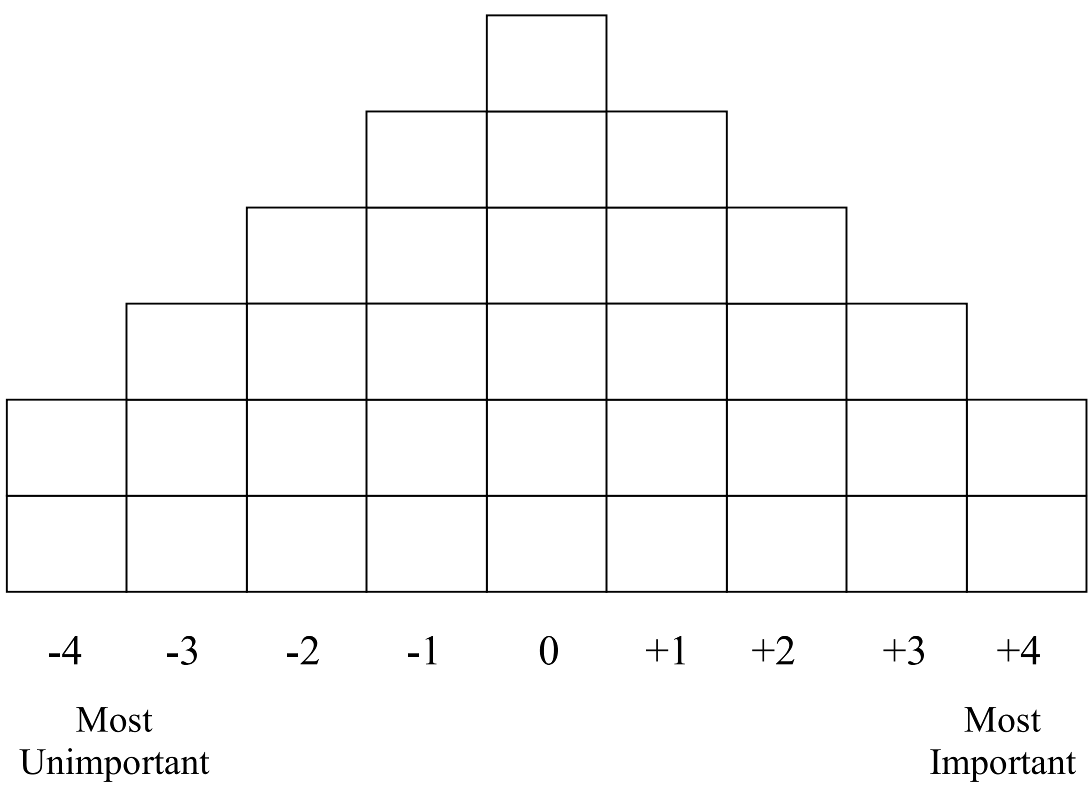
Continuing with the above example, Brown (1980) suggested that the investigator could choose ten statements from the concourse to fit each of the four categories, which would result in a Q-set of 40 (N=40). According to Watts and Stenner (2005, p. 75) a final Q-set between 40 and 80 is generally sufficient, because a smaller number may create problems of "adequate coverage," and a larger number may lead to a sorting process that is "unwieldy" for the participant. The potential problem of *adequate coverage* refers to the chance that the Q-set will not be representative of the full range of sentiments regarding the research topic.

It makes little difference which approach is chosen for the development of the Q-set as long as the investigator can justifiably claim that the final Q-set represents the full range of sentiments regarding the topic of interest (Watts & Stenner, 2005). To that end, it is advantageous to enlist the help of participants when developing the Q-set. Brown (1980, p. 190) asserted that "the preferred items in most instances are those freely given by subjects, with as little tampering and modification by the investigator as is practicable." Additionally, participation of members from different demographic groups is important because of Q-methodology's "focus on the subjective experiences of participants, its emphasis on context, and its privileging of the everyday and local" (Previte et al., 2007, p. 141-142). Therefore, input from participants can help to create a Q-set that is both more easily interpreted by Q-sorters (without potentially confusing researcher jargon), and more likely to include the full range of opinions surrounding a topic. Knowing when a Q-set is complete is difficult, and according to Watts and Stenner (2005, p. 75, emphasis in original), "there is a sense in which a Q-set can never really be complete (as there is always 'something else' that might potentially be said). Yet this is actually of little import…[because] a Q-set only needs to contain a representative *condensation of information.*"

4.2.2 Creation of the Q-Board

Step two involves the creation of the Q-board (Figure 4.1), which provides the framework (negative to positive point scale with a quasi-normal distribution) for the rank ordering exercise. The size of the Q-set will dictate the width of the point scale that is used for the Q-board, but it is typical for an 11 or 13-point scale (-5 to +5, or -6 to +6, respectively) to be employed (Watts & Stenner, 2005, p. 77).

Figure 4.1 Q-board used for this study



Brown (1980, p 200) elaborated further, “naturally, the larger the number of statements, the wider the range of available scores should be. As a rule, Q-samples smaller than N=40 can safely utilize a range of +4 to -4; from 40 to 60, a range of +5 to -5 is generally employed; beyond 60, +6 to -6 is not untypical.”

Brown (1980) also discussed the reasoning for choosing a steeper or flatter distribution, which is known as the distribution’s kurtosis. It is thought that "if the subject matter of the study is one in which most persons are expected to be relatively uninformed or uninterested, a distribution approaching normality is appropriate" (Brown, 1980, p. 200). In other words, if there is the feeling that participants will be apathetic to most statements, then it is prudent to develop a distribution with ample room in the middle (scores of zero). On the other hand, it is important to flatten the distribution and include more room at the extremes (scores of +/- 4, 5 or 6) when it is thought that "subjects are generally sensitized to most of the opinions in circulation and are anxious to agree or disagree with most, there being relatively few about which they are neutral" (Brown, 1980, p. 200).

The final aspect of the Q-board that needs explanation is the wording of the continuum range (most important to most unimportant in Figure 4.1). Brown (1980, p. 198) stated, “those things which are uncharacteristic of us are just as important, in a negative sense, as those that apply to us in a positive sense.” This reasoning is why the “Q-sort continuum usually ranges from ‘most’ to ‘most’” (Brown, 1980, p. 199). Watts and Stenner (2012, p. 80) are in agreement with this issue, and they asserted that a “most” to “most” range is critical, because “both poles are designed to capture very strong feelings, be they positive or negative. Items of relatively low importance, conversely, are likely to proliferate towards the middle of the distribution.” Even though certain studies do use the continuum range of “most” to “least,” it is something that Brown (1980) sees as an error in Q-methodology.

The difference between these two ranges can be exhibited in the context of this study. The participants will be required to rank order 34 statements, each representing a separate water-based ecosystem service derived from the SNF, from "most important" to "most unimportant" within the construct of the Q-board (Figure 4.1). Brown (1980) suggested that it may be helpful to first divide all the statements into three groups: most important, most unimportant, and the remainder. The statements that typically fall into the *remainder* category are the statements that the participant feels are neither important nor unimportant, or as Brown (1980, p. 196) explained those statements may also include those "which are unclear, meaningless or contradictory to him, or about which he is doubtful or uncertain." If the continuum range of “most” to “least” is employed then the middle category represents mid-range importance, as opposed to no importance. The consequence of this approach is the forced assumption that all statements have some importance, when in reality that may not be the case. This can be seen in the everyday activity of voting with the three voting choices of “yea,” “nay,” and “abstain.” The vote of “yea” indicates that you are in favor of what is being voted on, while “nay” indicates that you are opposed, and “abstain” is reserved for those that feel apathetic one way or another. If humans operated on the “most” to “least” continuum, then we would vote "strong-yea," "medium-yea," and "weak-yea." It has been suggested that this phenomenon is a function of "choice equilibrium" (Stephenson, 1953, p. 60 cited in Brown 1980, p. 199), and it is one of the reasons that Stephenson, the creator of Q-methodology, called for a center point of zero when Q-sorting. Stephenson (1974, p. 11) stated, "statements given zero on the Q-sort scale are those which 'do not matter' in the given situation. They contain no information. A point of no information must be the same, therefore, for all Q-sorts."

It may be good to pause for a moment, and discuss the criticism of Q-methodology's forced distribution and the rebuttal to that critique. The forced distribution refers to the requirement of the participant to follow the structure of the Q-board. For example, if the participant were sorting onto the Q-board in Figure 4.1, then they would be required to choose their two most important statements on the right, followed by their next three most important. On the opposite end of the spectrum, the participant would be required to choose their two most unimportant statements, followed by their next three most unimportant, etc. It has been asserted, "that the forced-choice method constrains the subject unduly by restricting the individuality of his response" (Brown, 1980, p. 201). As a response to this criticism, Brown (1980, p. 201) noted that for a study with 33 statements in the Q-set the respondent has "in excess of 11,000 times more different ways to sort the statements, even in the forced distribution, than there are people in the world!" Granted this was the population of the world in 1980, however; the number of possible Q-sort combinations is still well into the billions.

There are also two statistical critiques targeted at the forced distribution aspect of the Q-sort, which is that it "violates the assumption of independence required for the analysis of variance, as well as the assumption of equal intervals required for the application of Pearson's product-moment correlation" (Cronbach & Gleser, 1954; Gaito, 1962 cited in Brown, 1980, p. 201). In order to refute these sentiments, Brown (1980) created 14 distributions for the Q-board using 33 statements, and then correlated and factored each different distribution. Despite the range of distribution types, from complete rank ordering (1,2,3,4,5…33) to dichotomous (17 valued at -4, and 16 valued at +4), the factor loadings show a high correlation, which is reflected by the factor loadings being close to one for almost all distributions. In conclusion, Brown (1980, p. 289) noted that "within the factor-analytic framework, (1) distribution effects are virtually nil, the existence of factors being affected almost entirely by the patterns of item placement, and (2) the interval-ordinal distinction is of no importance; i.e., the same results occur whether or not intervals are assumed to exist." Regarding this topic, Watts and Stenner (2005, p. 77, emphasis in original) stated, "the chosen distribution actually makes *no noticeable contribution* to the factors which emerge from a particular study (and this is the main reason why a complete rank ordering of the items is also unnecessary). Contradictory as it may seem, therefore, a forced distribution is actually no more restrictive than a 'free' distribution." If these rebuttals offered do not assuage the concerns of critics, then Brown (1980) explained that the participants could be given freedom to break the forced distribution, an act that would not change the results much. However, Brown (1980, p. 203) warned that it may be best to follow the rules of the distribution in order to encourage the participants to "make distinctions that they might not otherwise volunteer but of which they are generally capable."

4.2.3 Recruitment of Q-Sort participants

The third step requires the recruitment of Q-sort participants, which is only described as the third step because it is a process that is similar to the development of the Q-set and, as a result, its understanding is facilitated by discussing the development of the Q-set first. In reality, it is more appropriate to build a list of potential participants throughout the study, because participant involvement can be employed during both the development of the Q-set and the completion of the Q-sort.

The group of participants selected to complete the Q-sorts are referred to as the "P-set" (Brown, 1980, p. 191). It is imperative that as many participant viewpoints are represented in the P-set as possible. According to Watts and Stenner (2005, p. 79), "one ought to ensure that Q-sorts are gathered from as many of the obviously pertinent demographic groups as possible." In order to maximize the possibility that all *pertinent demographic groups* are represented in the P-set, Brown (1980) suggested that the principles of experimental design should be applied. The experimental design approach used to construct the P-set is similar to that used to construct the Q-set, which "is intended to serve as a formula for purposes of selecting persons expected to have viewpoints pertinent to the problem under investigation. As a general rule, the Q-sort is administered to persons who, on *a-priori* grounds, are expected to define a factor" (Brown, 1980, p. 194, emphasis in original).

A random sampling approach using a large number of participants is not necessarily appropriate in Q-methodology, because the main objective of the method is to understand the full range of opinions regarding some topic. Therefore, Watts and Stenner (2005, p. 79) suggested that strategic sampling is the most appropriate, especially in situations when participants are likely to express an “interesting or pivotal viewpoint.” As a result, participants are chosen for “comprehensiveness and diversity, rather than representativeness or quantity” (Eden et al, 2005, p. 417). Brown (1980, p. 191) reinforced this point when he noted that “only a few subjects are required” in a Q-methodological study, which is evident by the nine subjects in the Lipset-study example. Stainton Rogers (1995) asserted that a P-set of 40 to 60 participants is most effective in capturing a diverse range of viewpoints, but Watts and Stenner (2005, p. 79) added that this number is “only a ‘rule-of-thumb’, however, for highly effective Q-studies can be carried out with far fewer participants.”

In order to increase the chances of including all pertinent demographic groups in a P-set, Q-methodologists (Brown, 1980; McKeown & Thomas, 1988; Watts & Stenner, 2005) employ Arnold’s (1970) dimensional sampling as a method for categorizing the different attitudes that may exist in relation to some research topic. According to Arnold (1970, 147), “the goal of dimensional sampling is to provide a framework for drawing a purposive sample representative of the universe to which one wishes to generalize.” In other words, when constructing the P-set, it is helpful to categorize the various types of viewpoints that potential participants may have, as well as the characteristics possessed by participants that may impact those viewpoints.

For example, McKeown and Thomas (1988, p. 38) illustrated a dimensional-sampling approach in their discussion of the hypothetical design of a P-set for a Q-study on gay rights, which categorizes the P-set into four dimensions with each dimension being defined by types. The four dimensions and their types in parentheses are: sex (male and female); age (20-40 years old, 41-60 years old, and 61 and older); education (college and no college); and groups (mainline protestant churches, evangelical-fundamentalist churches, and gay/lesbian organizations). In this P-set design there are 36 combinations, which is the product of the number of types in each dimension: (2 types for sex) *X* (3 types for age) *X* (2 types for education) *X* (3 types for groups) = 36 combinations. In the example by McKeown and Thomas (1988) the formula used to calculate the P-set is as follows:

$$\text{P-set (n)} = (\text{Criteria})(\text{Replications}) = (36)(3) = 108 \text{ participants}$$

where the criteria are the 36 combinations defined above, and the replications is the number of persons from each combination. McKeown and Thomas (1988) decided that three replications of each combination was sufficient, which gave a total P-set of 108. It is unclear why replication is used in their example, but presumably it is used to investigate variability among participants in the same combination group. Variability within viewpoints among a group of subjects that are perceived as similar could indicate that there is some latent characteristic that is influencing the respondents' perspective, which could prompt further investigation and facilitate a deeper understanding of the data. It is also unclear why 3 replications were chosen, as opposed to some other number. One possible guiding principal for choosing the number of replications, or to replicate at all, would be to choose the number of replications that results in a particular size for the P-set. For example, if an investigator was aiming for a P-set in the range of 40 to 60 people and, using experimental design, developed 25 combinations, then 2 replications would be result in a P-set of 50, and would be deemed appropriate.

Even though Brown (1980, p. 194) does not mention any replication of the various combinations in the P-set, he does mention a "law of diminishing returns" that asserts itself when adding extra dimensions. When creating a P-set, an investigator has to manage the addition of dimensions that will potentially yield different perspectives without adding too many dimensions, which can result in an unrealistic data collection endeavor.

According to Watts and Stenner (2005, p. 80), there are situations when "participants may not divide so obviously along lines prescribed by demographic characteristics," which may make the dimensional sampling approach difficult. In such cases, when acting on *a-priori* assumptions is ill advised, Watts and Stenner (2005, p. 80) suggested the use of opportunistic sampling, "at least in the first instance, or until a series of Q-methodological explorations (and their emergent factors) provide empirical justification for the belief that certain viewpoints 'belong' exclusively to specific demographic groups."

Understanding the desired composition of the P-set is only part of the process, because the researcher in a real life scenario must actually find participants that he/she feels will represent the full range of perspectives regarding the topic of investigation. Vugteveen et al. (2011) contacted subjects by creating a list of 200 potential stakeholders using specific selection criteria in the context of Dutch water management. The 200 potential participants were then contacted via email, and of those that responded positively to their query, 56 were selected based on the selection criteria used to create the initial list of potential stakeholders.

Identification of potential Q-sort participants depends on the topic being investigated. Cuppen et al. (2010) relied on newspaper articles, news-websites, and the snowball technique to identify stakeholders for their study on energy options from biomass. The snowball sampling technique, or chain referral method, yields a "study sample through referrals made among people who share or know of others who possess some characteristics that are of research interest" (Biernacki & Waldorf, 1981, p. 1981). Snowball sampling can be used as the main approach for obtaining informants for a research study, or as a secondary means to "assist researchers in enriching sampling clusters, and accessing new participants and social groups when other contact avenues have dried up" (Noy, 2008, p. 330). The snowball technique used by Cuppen et al. (2010, p. 582) asked respondents to "mention someone with a different, and someone with a similar perspective," which is an instruction that decreases the chance that the snowball technique results in a homogenous sample, an outcome that is not desirable in Q-methodology.

Regardless of the approach used in creating the P-set, it is important to remember that Q-methodology is "intended to identify subjectivities that exist, not to determine how those subjectivities are distributed across a population" (Brown et al., 1999, p. 602). Therefore, the goal of the P-set is not to be representative of the population being studied but, ideally, it should include all perspectives surrounding the topic of investigation, no matter how prevalent.

4.2.4 Completion of the Q-Sort by participants

Step four requires the participants to rank order the statements from the Q-set in an activity known as the Q-sort. This exercise will require the participants, or stakeholders in the case of this study, to "decide what is 'meaningful' and hence what does (and what does not) have value and significance *from their perspective"* (Watts & Stenner, 2005, p. 74, emphasis in original). The participants are given a deck of shuffled cards (each card contains one statement from the Q-set) and a Q-board. The Q-sorting process typically starts with a set of instructions given by the investigator to the participant. If the study was interested in understanding how people perceived their relationship to their spouse, for example, then they might be asked to: "Please rank the cards onto the Q-board from most characteristic to most uncharacteristic of your relationship with your spouse." Or in the case of this study of the importance of water-based ecosystem services, the participants were instructed to: "Please rank the statements on the cards from most important to most unimportant from your perspective. Each statement represents a water-based ecosystem service derived from the Shoshone National Forest."

After the Q-sort is completed, the researcher should conduct a follow-up interview, which, in addition to factor analysis (to be discussed in Chapter 4.2.5), will help to give the data meaning. During the follow-up interview, the researcher allows the participant to give an explanation for their sorting. Brown (1980, p. 200) suggested that the follow-up interview is an often-overlooked step that is quite important, because it is at this time that the "subject is given the opportunity to expound on his reasoning for ranking the statements in his unique way." Stergiou and Airey (2011, p. 316) also stressed the importance of the follow-up interview, and they do so for two reasons:

> First, the Q-sort represents the 'skeleton' of subjectivity, which only becomes interpretable through the comments and reflections of the participants. Second, the interview process allows both the researcher and the test persons to perceive interrelations and inconsistencies in the Q-sorts and to refer to these directly.

Inconsistencies could be those situations in a Q-sort that are counter-intuitive, and these instances can help to uncover unique and nuanced perspectives, or potential mistakes (e.g. misreading) by the participant. For example, in this study about the importance of water-based ecosystem services, it would raise a flag if a Native American participant ranked the non-Native American cultural and spiritual values higher than the Native American cultural and spiritual values. Following the Q-sort, this unique aspect of the participant's ranking could be addressed, and in the process it could uncover a unique perspective, or it could also simply highlight an oversight that could subsequently be corrected.

4.2.5 Data analysis

The fifth step is the data analysis stage. The goal of the Q-sort is to obtain "insight into the values and preferences held by the public" (Steelman & Maguire, 1999, p. 362), but the subjectivity of the participant that is expressed in the Q-sort is not immediately evident, and it is the use of factor analysis that will give the raw data (Q-sorts) meaning. Understanding of the data in Q-methodology is facilitated by applying the logic of abduction, which is a not-so-well-known form of reasoning apart from deduction and induction (Watts & Stenner, 2012). Deduction is "top-down" logic, which begins with a hypothesis and ends with the testing of that hypothesis through observation; induction is "bottom-up" logic, which begins with observations and ends with "generalizations and descriptions" of the object being observed (Watts & Stenner, 2012, p. 38). Abduction, in contrast, consists of "studying the facts and devising a theory to explain them" (Peirce, 1931/1958, p. 90 cited in Watts & Stenner, 2012, p. 39). Even though abduction may sound similar to induction because they both start with studying or observing the facts, Watts and Stenner (2012, p. 39, emphasis in original) stressed that the former is in "pursuit of an *explanation* and new insights," and the latter is seeking to "establish a generally applicable *description* of the observed phenomenon." The use of abduction in Q-methodology is consistent with a previously made point regarding the exploratory nature of Q.

4.2.5.1 Factor analysis

Kim and Mueller (1978, p. 9) described factor analysis as a "variety of statistical techniques whose common objective is to represent a set of variables in terms of a smaller number of hypothetical variables." At a basic level, the goal of factor analysis is one of data reduction, which is "based on the fundamental assumption that some underlying factors [(unobserved variables)], which are smaller in number than the number of observed variables, are responsible for the covariation among the observed variables" (Kim & Mueller, 1978, p.12). See Appendix B.1 for a basic factor model.

Factor analysis is completed in four basic steps, which Kim and Mueller (1978, p. 46) described as: "(1) the data collection and preparation of the relevant covariance matrix, (2) the extraction of the initial factors, (3) the rotation to a terminal solution and interpretation, (4) construction of factor scales and their use in further analysis." This section will discuss these four steps in detail in the order outlined above.

4.2.5.2 The covariance matrix

The data collection step has already been discussed and, so, it is appropriate to move into a discussion of the preparation of the covariance matrix, which is also known as the correlation matrix (see Appendix B.2 for a discussion of covariance, variance, mean and correlation coefficient). The correlation matrix is the starting point of factor analysis, because it is from the correlation matrix that the factors are extracted.

The development of the correlation matrix is typically done using the known relationship between the observed variables. It is beneficial to discuss the development of the correlation matrix in the context of Q-methodology and R-methodology, because each methodology focuses on correlating different types of variables and, as a result, the correlation matrices are different. In Q-methodology, the variables being analyzed are the Q-sorts, which are also the participants completing the Q-sorts. In contrast, methods that employ the R-technique focus the analysis on tests or traits. In Q-methodology, the result of analysis is the development of factors (group perspectives) based on shared values. In R-methodology, the result is the development of factors based on shared traits. Brown et al. (1999, p. 602) articulated this point concisely:

> Q-methodology seeks to understand how individuals think (i.e., the structure of their thoughts) about the research topic of interest. R methodology identifies the structure of opinion or attitudes in a population. Thus, the results of Q-method will identify how an individual, or individuals with common views, understand an issue; the results of R methods describe the characteristics of a population that are associated statistically with opinions, attitudes, or behavior (e.g., voting) being investigated.

The contrast between Q-method and R method can be furthered by considering Brown's (1980, p. 14) assertion that factor analysis in R "breaks up a phenomenon…into separate parts," whereas the factor analytic process in Q is "more gestaltist and wholistic." According to Watts and Stenner (2005, p. 70), the gestaltist approach "means it can never 'break-up' its subject matter into a series of constituent themes." In other words, when analyzing a resulting factor in Q-methodology, the investigator is considering a certain number of whole people that load onto a factor, and how those people perceive some research topic. As opposed to R method, where an investigator is analyzing a factor that is defined by certain traits, and not by a group of individuals.

Consider the voting behavior mentioned above, for example, where a hypothetical-R factor may find that young minorities in a sample tend to vote Democrat, which would be the result of a high correlation between the observed variables (age, race, and party affiliation) in the R-correlation matrix. However, as will be seen below, the correlation of traits in R is an aggregate of the two observed variables (traits) being correlated, which is then divided by the sample size (number of participants). As a result of this procedure, the analysis of the resulting factors will not allow an investigator to say anything about the individuals participating in the study.

The correlation matrix in a Q-methodology study is developed by starting with a matrix of raw data, as shown in Table 4.1, where the Q-sorts are arranged in the columns (W = total number of Q-sorts), the statements for the Q-set are arranged in the rows (N = total number of statements) and, for illustrative purposes, the numbers in Table 4.1 are scores assigned for each statement by the Q-sorter. The far right column in Table 4.1, which will be explained in greater detail below, are the squared differences in Q-sort scores between persons 1 and 2, with the value of 250 representing the sum of those squared differences for all statements. The matrix would continue with $d_{1,3}^2$, $d_{2,3}^2$, and so on, until the difference in score between all Q-sorts was computed.

Brown (1980) explained the process of deriving the correlation matrix from the matrix of raw data. The correlation coefficient between each Q-sort is computed by finding the sum of the squared differences between the scores attributed to each statement (e.g. $d_{1,2}^2$=

$(-4 - 2)^2 = 36$) where the scores (-4 and +2) are taken from the column placement of the statement on the Q-board (Figure 4.1).

Table 4.1 Raw data matrix in Q

Persons (Q sorts)

		1	2	…	W	$d_{1,2}^2$
Statements (items)	1	-4	+2	…	-3	36
	2	+1	+3	…	-2	4
	…	…	…	…	…	…
	N	0	4	…	1	16
					$\sum_{n=1}^{N} d^2$	250

The equation used for computation of the correlation coefficient in Q-methodology is as follows (see Appendix B.3 for the link between this equation and the covariance equation presented in Appendix B.2):

$$r_{1,2} = 1 - \frac{\sum_{n=1}^{N} d^2}{2Ns^2}$$

where d is equal to the difference between scores for each statement, N is the number of statements in the Q-set, and s^2 is equal to the variance for the forced distribution. The variance for the forced distribution is represented by the following formula (Brown, 1980, p. 264):

$$s^2 = \frac{\sum fx^2}{N}$$

where x^2 is equal to the square of the raw score (-4,-3,…,3,4 in our example of a Q-board in Figure 4.1) and f is the frequency at which it occurs on the Q-board (i.e. the number of statements that can be given that score).

Using Table 4.1 as an example, person 1 scored statement 1 as -4, and person 2 scored statement 1 as +2 (again, both of these scores would be found by looking for the column placement of statement 1 by each Q-sorter), which yields a difference of 6. The difference would then be squared ($6^2 = 36$), and summed for all statements in the Q-set for person 1 and person 2. To continue the example, let us assume that the sum of the squared differences of the statements between person 1 and 2 is 250. The final aspect of the correlation coefficient equation that needs calculating is the denominator, which is as follows:

$$2Ns^2 = 2N(\sum fx^2 / N)$$

To continue the calculation using the Q-board in Figure 4.1, the scores of -4, -3, -2, -1, 0, +1, +2, +3, and +4 have frequencies of 2, 3, 4, 5, 6, 5, 4, 3, 2, respectively. Therefore, fx^2 for the far left column of the Q-board is expressed by: $(2)(-4^2) = 32$, and the column with a score of -3 is expressed by: $(3)(-3^2) = 27$, and so on and so forth. After several calculations and remembering that N equals the total number of statements (which can also be computed by totaling the frequencies), the variance of the forced distribution in this example is as follows:

$$s^2 = \sum fx^2/\mathrm{N} = 160/34 = 4.71$$

The denominator for the correlation coefficient equation can now be calculated:

$$2\mathrm{Ns}^2 = 2(34)(4.71) = 320.28$$

Calculating the correlation coefficient between person 1 and person 2 in this example is now possible:

$$r_{1,2} = 1 - \frac{\sum_{n=1}^{N} d^2}{2Ns^2} = 1 - \frac{250}{320.28} = 1 - .78 = .22$$

By calculating the correlation coefficients between all Q-sorts, one is able to create a correlation matrix (W by W, where W is number of Q-sorts) that can subsequently be factor analyzed.

For an R-methodological study, the development of the correlation matrix is similar, except that the matrix of raw data focuses on "the relationship between traits, with scores being expressions of individual differences for the various traits in a sample of persons" (Brown, 1980, p. 12). The matrix of raw data for an R-study is shown in Table 4.2, where the sample (N = total number of population being sampled) is represented in the rows, tests or traits (W = total number of tests) are in the columns, and the values (A_1, etc.) that each unit of the sample scored for each trait. It should be noted that the sample in an R-study does not need to be participants. For example, Brown (1980) illustrates an R-study where the sample is days, and the tests are different types of weather on those days.

The correlation coefficient between traits A and B, which have been standardized (see Appendix B.4 for standardization and computation of the correlation coefficient in R), is expressed by the following equation:

$$r_{z_a\,z_b} = \frac{\sum z_a z_b}{N}$$

where N is the number in the sample, and z is the normalized value of the trait being measured. By calculating the correlation coefficient between all traits in the manner shown in Appendix B.4, a W by W correlation matrix would result, where W is the number of traits being measured.

Table 4.2 Raw data matrix in R

		Tests or Traits			
		A	B	…	W
Sample	1	A_1	B_1	…	W_1
	2	A_2	B_2	…	W_2
	…	…	…	…	…
	N	A_N	B_N	…	W_N

A common misconception about the correlation matrix in Q-method is that it is "the transpose of the R matrix –i.e., as the correlation and factorization by rows of the same matrix of data that in *R* is factored by columns" (Brown, 1980, p. 13). It is an understandable misconception, because William Stephenson described the *Q*-technique of factor analysis as an inverted version of the R-technique of factor analysis (Stephenson, 1936). The inverted version in Q, however, was not simply the transposition of the R-data matrix, but a standardization of the rows instead of the columns (Stephenson, 1936), which is an adjustment that allows persons to be correlated instead of tests. Stephenson (1953, p. 56) was explicit in addressing this misconception when he stated:

> It may be seen how erroneous it was, therefore, to suppose that only one matrix of data is ever at issue, fundamentally, which can be correlated by rows or by columns as a matter of convenience. Each set of data involves its own postulates and assumptions. A matrix for R is one thing, that for Q-quite another matter.

4.2.5.3 Extraction of initial factors

As Brown (1980, p. 209) explained, "the factoring process begins…with the correlation matrix." Now that the correlation matrix has been explained, it is time to discuss the extraction of the initial factors. This step of factor analysis, and all subsequent steps, will be presented in the context of Q-methodology. Although the remainder of this Chapter focuses on Q, the methods also apply to R, because "once the table of correlations has been derived, the process of factoring [between Q and R] is, in principle, the same" (Brown, 1980, p. 208).

Data reduction in Q-methodology is typically done using one of two techniques: (1) factor analysis using the centroid method; or (2) principal components analysis (PCA). The centroid method is the recommended method of Watts and Stenner (2012), and it was the first to be fully developed in factor analysis, which was mainly due to its computational ease (Brown, 1980). PCA boasts the ability to extract factors that explain the greatest amount of variance; however, Burt (1972) and Brown (1980) illustrated that both methods produce similar results. The factor-extraction procedure explained here is the centroid method, and it is taken from Brown (1980). It should also be noted that doing factor analysis by hand is obsolete, and there are a number of computer programs that can complete the process in a negligible amount of time. Watts and Stenner (2012) noted that SPSS can be used to analyze Q-data, but it is not recommended because SPSS is configured to run analysis for R-methodologies. Two statistical packages that are tailored towards Q-methodology analysis are PQMethod, which was used for this project and was created by Schmolck (2011a), and PCQ for Windows. Watts and Stenner (2012) explained that PCQ for Windows may be easier to use, but due to a cost of $400 dollars it is suggested that the free software (PQMethod) be used. Despite the obsoleteness of doing factor analysis by hand, this investigator feels that articulation of the process will inevitably improve the understanding of the resulting factors.

The first step, prior to factoring, is the maximization of the positive value of the correlation matrix. This is a task that is completed through reflection (Holley, 1947 cited in Brown, 1980), and is simply the reversing of all signs in the rows and columns that have an overall negative sum. Brown (1980, p. 209) attempted to placate the potential critics of this move when he noted, “although this involves the manipulation of figures, all is not arbitrary, for what is arbitrarily done at the outset is compensated for by being arbitrarily undone at the conclusion.”

Once the positive value of the correlation matrix is maximized, then the diagonal values must be chosen. The diagonal values are the correlation of a variable with itself and, in many cases (R-methods), that value would be 1.0. However, in Q-methodology these values would be the correlation that a Q-sorter would have with themselves. In theory this value could still be 1.0, but Brown (1980, p. 211) posited that in a real life scenario a Q-sorter taking the same Q-sort twice, with a day or so between Q-sorts, would probably never correlate as highly as 1.0. Therefore, the preferred diagonal value would be test-retest coefficient (reliability coefficient) for each participant, however, this would require the participant to take the Q-sort twice, which is most likely not an option in many research projects. Alternatively, the diagonal value could be the communality (h^2) (see Appendix B.5 for discussion on communality and reliability), but this is a value that is not known prior to the factor extraction and, therefore, it would need to be an estimate (Brown, 1980). The chosen diagonal value is actually of little import because, as will be seen, the next step in factor extraction will correct any inaccuracies.

Once a diagonal value is chosen and entered into the correlation matrix then it is time to extract the first factor. Table 4.3 is taken from Brown (1980), and is an example of how the estimate for factor A of the Lipset study was obtained. The diagonal values are left blank in the matrix, however, an estimate is required to proceed with the extraction of the estimate loading for factor A. For the purposes of Brown's (1980) example, the value used for the diagonal space is the sum of the correlation coefficients for each column divided by the number of Q-sorts minus one (W - 1). This value is represented by $\bar{r}_i$ in Table 4.3 (where i is equal to the column number), which is a value that contributes to the first estimate of the column total:

$$t_{1_i} = \sum r_i + \bar{r}_i$$

where t_{1_i} is the first estimate for the total value of each column *i,* and $\sum r_i$ is the sum of the correlation coefficients for each column not including the diagonal values, which are represented by $\bar{r}_i$. It is now possible to find the first estimate of the sum of the entire correlation matrix, which is represented by:

$$T_1 = \sum t_{1_i}$$

The first estimate of the loading of each participant (Q-sort) onto factor A is acquired with the following operation:

$$f_{1_i} = t_{1_i} / \sqrt{T_1}$$

The final aspect of Table 4.3 that needs to be covered is $f_{1_i}^2$, which is the square of the factor loading estimate and will subsequently be used as a more accurate estimate of the diagonal value (a point that will be discussed during the iteration process below) instead of $\bar{r}_i$.

The process of obtaining the first estimate of the factor loading (f_{1_i}) required the use of $\sqrt{T_1}$ as the divisor of t_{1_i}. Brown (1980, p. 216, emphasis in original) explained, the individual loadings for factor A are estimated by "forming the ratio of the row (or column) total to the grand total of the factor loadings, but the total of the matrix, *T*, is the *square of the sum* of the loadings rather than merely their sum; consequently, the appropriate divisor is not *T*, but $\sqrt{T}$."

Table 4.3 Original correlations (reflected) and extraction of factor A[a]

	∞1	∞2	3	4	∞5	6	7	∞8	9	
∞1	-	54	-21	-23	10	23	32	24	-05	
∞2	54	-	08	-09	18	03	16	38	-07	
3	-21	08	-	40	54	09	05	09	11	
4	-23	-09	40	-	56	28	17	-06	03	
∞5	10	18	54	56	-	06	13	02	03	
6	23	03	09	28	06	-	62	37	-21	
7	32	16	05	17	13	62	-	29	-03	
∞8	24	38	09	-06	02	37	29	-	21	
9	-05	-07	11	03	03	-21	-03	21	-	
$\sum r_i$	0.94	1.21	1.15	1.06	1.62	1.47	1.71	1.54	0.02	
$\bar{r}_i$	0.12	0.15	0.14	0.13	0.20	0.18	0.21	0.19	0.00	
t_{1_i}	1.06	1.36	1.29	1.19	1.82	1.65	1.92	1.73	0.02	12.04 = T_1
f_{1_i}	0.31	0.39	0.37	0.34	0.52	0.48	0.55	0.50	0.01	3.47 = $\sqrt{T_1}$
$f_{1_i}^2$	0.10	0.15	0.14	0.12	0.27	0.23	0.30	0.25	0.00	$f_{1_i} = t_{1_i} / \sqrt{T_1}$
t_{2_i}	1.04	1.36	1.29	1.18	1.89	1.70	2.01	1.79	0.02	12.28 = T_2
f_{2_i}	0.30	0.39	0.37	0.34	0.54	0.49	0.57	0.51	0.01	3.50 = $\sqrt{T_2}$
$f_{2_i}^2$	0.09	0.15	0.14	0.12	0.29	0.24	0.32	0.26	0.00	$f_{2_i} = t_{2_i} / \sqrt{T_2}$
t_{3_i}	1.03	1.36	1.29	1.18	1.91	1.71	2.03	1.80	0.02	12.33 = T_3
f_{3_i}	0.29	0.39	0.37	0.34	0.54	0.49	0.58	0.51	0.01	3.51 = $\sqrt{T_3}$
$f_{3_i}^2$	0.08	0.15	0.14	0.12	0.29	0.24	0.34	0.26	0.00	$f_{3_i} = t_{3_i} / \sqrt{T_3}$
t_{4_i}	1.02	1.36	1.29	1.18	1.91	1.71	2.05	1.80	0.02	12.34 = T_4
f_{4_i}	0.29	0.39	0.37	0.34	0.54	0.49	0.58	0.51	0.01	3.51 = $\sqrt{T_4}$
$f_{4_i}^2$	0.08	0.15	0.14	0.12	0.29	0.24	0.34	0.26	0.00	$f_{4_i} = t_{4_i} / \sqrt{T_4}$

Notes: [a] Decimals to two places omitted in *r* matrix

∞ Columns that have been reflected to maximize positive value of the correlation matrix

Source: Adapted from Brown (1980, p. 210).

Table 4.4 and the following discussion are taken from Brown (1980, p. 215-216) and explain why the factor loadings are estimated by $\frac{t_{1_i}}{\sqrt{T_1}}$. The factor A loadings are taken from f_{4_i} row in Table 4.3, the matrix is populated by the cross-products of the factor loadings (e.g. $(f_{4_1})(f_{4_2}) = (0.29)(0.39) = 0.11$) and the diagonal values are the squares of the loadings, which correspond with $f_{4_i}^2$ in Table 4.3. Also, *t, T,* and $\sqrt{T}$ in Table 4.4 are nearly equal to t_{4_i}, T_4, and $\sqrt{T_4}$ with small differences due to rounding errors.

Table 4.4 Relationship of factor loadings to correlation coefficients[a]

		∞1	∞2	3	4	∞5	6	7	∞8	9	
	Factor A Loadings	0.29	0.39	0.37	0.34	0.54	0.49	0.58	0.51	0.01	*t*
∞1	0.29	(08)	11	11	10	16	14	17	15	00	1.02
∞2	0.39	11	(15)	14	13	21	19	23	20	00	1.36
3	0.37	11	14	(14)	13	20	18	21	19	00	1.30
4	0.34	10	13	13	(12)	18	17	20	17	00	1.20
∞5	0.54	16	21	20	18	(29)	26	31	28	01	1.90
6	0.49	14	19	18	17	26	(24)	28	25	00	1.71
7	0.58	17	23	21	20	31	28	(34)	30	01	2.05
∞8	0.51	15	20	19	17	28	25	30	(26)	01	1.81
9	0.01	00	00	00	00	01	00	01	01	(00)	0.03
	$3.52 = \sum f$										$T = 12.38$
	$0.39 = \bar{f}$										$\sqrt{T} = 3.52$
	$0.15 = \bar{f}^2$										$\bar{r} = 0.15$

Notes: [a] Decimals to two places omitted in matrix
∞ Columns that have been reflected to maximize positive value of the correlation matrix
Source: Brown (1980, p. 215).

In order to understand the connection between the factor loadings and the correlation coefficients, Brown (1980, p. 216) noted, “the sum of any row (or column) would be the sum of the factor loadings times the loading for that row.” Using row 1 in Table 4.4 as an example, Brown (1980, p. 216) presented the following equation, which has been slightly modified by the investigator to match the slight modifications made to Table 4.3:

$$\begin{aligned} t_{4_1} &= f_{4_1} f_{4_1} + f_{4_1} f_{4_2} + \ldots + f_{4_1} f_{4_9} = f_{4_1}(f_{4_1} + f_{4_2} + \ldots + f_{4_9}) \\ &= 0.29(0.29 + 0.39 + \ldots + 0.01) \\ &= 1.02 \end{aligned}$$

It then becomes apparent that the grand total of the matrix is equal to the square of the sum of the factor loadings (Brown, 1980, p. 216):

$$
\begin{aligned}
T_4 &= f_{4_1}(f_{4_1} + ... + f_{4_9}) + f_{4_2}(f_{4_1} + ... + f_{4_9}) + ... + f_{4_9}(f_{4_1} + ... + f_{4_9}) \\
&= (f_{4_1} + f_{4_2} + ... + f_{4_9})(f_{4_1} + f_{4_2} + ... + f_{4_9}) \\
&= (\sum_{i=1}^{I} f_{4_i})^2
\end{aligned}
$$

It is important to keep in mind that the correlation matrix is populated by correlation coefficients, which are the covariances of standardized variables. The covariance of two variables is simply the average product of the deviation of two variables from their means, and the covariance of two standard variables is the average of their product because they share the same mean of zero (see Appendix B.2). It follows that the estimation of a factor loading, which is indicative of the magnitude of the contribution of a Q-sorter's correlation to the overall correlation of the matrix, would be obtained by finding the proportion of a Q-sorter's correlation with the other Q-sorters relative to the rest of the correlation matrix. However, because the total value of the correlation matrix is the square of the sum of the factor loadings, then it is appropriate to divide the sum of each column by the square root of the total matrix.

The multiple *t*'s, *T*'s and *f*'s present in Table 4.3 is a result of the iteration process that will eventually lead to the accepted factor loadings for factor A. The first factor estimate is represented by f_{1_i} in Table 4.3, which means that Q-sort 1 correlates with factor A with a value of 0.31, Q-sort 2 with a value of 0.39, and so on. However, the first factor estimate is deemed unsatisfactory, because according to Brown (1980, p. 212) the estimates are acceptable if "each [$f_{1_i}^2$] is sufficiently close to the diagonal estimate for the same column, i.e., if [$f_{1_i}^2 \approx \bar{r}_i$], where by 'sufficiently close' is meant within +/- 0.02." The first factor estimates are unacceptable because Q-sorts 5, 6, 7, and 8 each have a difference between $f_{1_i}^2$ and $\bar{r}_i$ of 0.07, 0.05, 0.09, 0.06, respectively. Due to unacceptable factor estimates, the researcher is required to try again, but this time the $\bar{r}_i$ is replaced by $f_{1_i}^2$ in the diagonals and the columns are re-summed using the new estimate, which is an estimate of the variance explained by the common factor (see Appendix B.6 for discussion on components of variance). After the second iteration, the values of $f_{2_i}^2$ and $f_{1_i}^2$ are close enough to stop the process and accept f_{2_i} as the loadings for factor A, however, Brown (1980) continues for a couple more iterations for the sake of precision. Also, continuing with more iterations highlights the previously made point that the initial value chosen for $\bar{r}_i$ (between 0 and 1) is of little consequence, because through the iterations one will eventually arrive at a point where an improvement of the squared factor loadings is impossible (i.e. $f_{3_i}^2$ and $f_{4_i}^2$ are equal for all nine variables).

A discussion of the values for $\bar{f}^2$ and $\bar{r}$ in Table 4.4 can further explain the relationship between the factor loadings and the original correlation coefficients because, since $T = (\sum f)^2$, then it should follow that the average correlation coefficient in Table 4.3 is equal to square of the average factor loading. Notice that $\bar{f}^2$ is the square of the mean of the factor loadings, which can be represented by:

$$\bar{f}^2 = (\frac{f_{4_1} + f_{4_2} + ... + f_{4_9}}{W})^2 = (\frac{3.52}{9})^2 = 0.39^2 = 0.15$$

and the average correlation coefficient in Table 4.3 can be expressed by the total value of the matrix divided by the number of spaces in the matrix (which is the square of the total Q-sorts):

$$\bar{r} = \frac{T}{W^2} = \frac{12.34}{81} = 0.15$$

Following the acceptance of the loadings for factor A (f_{4_i}), the factor analyst is required to take a couple more steps before the extraction of factor B can commence. This is assuming that there is need to extract another factor, which is a question that can be answered by subtracting out the "effect of factor A" (Brown, 1980, p. 213). Consider Q-sorts 1 and 2 as an example, which had an original correlation of $r_{1,2} = 0.54$. Now it is known that factor A associates with Q-sorts 1 and 2 in the amounts of 0.29 and 0.39, respectively. In order to remove the effect of factor A, and be left with the "residual correlation," the following equation can be used (Brown, 1980, p. 213):

$$\begin{aligned} r_{1,2*A} &= r_{1,2} - f_{4_1,A} f_{4_2,A} \\ &= 0.54 - ((0.29)(0.39)) = 0.54 - 0.11 \\ &= 0.43 \end{aligned}$$

where the notation *A represents the removal of the impact of factor A from the overall correlation between Q-sorts 1 and 2. The residual correlation between Q-sorts 1 and 2, after the effect of factor A is removed, is 0.43. This process is completed for all Q-sorts, at which point, the researcher can decide whether another factor needs to be extracted. If all the residuals were close to zero, it means that all Q-sorts were almost the same and there is a one-factor solution. Brown (1980, p. 214) asserted, "the existence of many residuals in excess of +/- 0.30, however, indicates the likelihood that at least a second attitude (factor) is in existence, and perhaps a third."

In Brown's (1980) Lipset-study example, there is a need to extract another factor. Before moving on, though, the researcher must account for the arbitrary reflection that was done with the original correlation matrix. Therefore, the residual correlations for variables 1, 2, 5, and 8 must be "dereflected" in that order (Brown, 1980, p. 215). Once this task is completed, it is time for the extraction of the second factor from the correlation matrix of residual correlations remaining after the effect of factor A is removed. The process of extracting subsequent factors is the same as that for extracting the first factor and, for that reason, the mechanics of extracting more factors will not be discussed.

The final issue that needs to be covered is when to stop factoring. The highest number of factors that could be extracted is equal to the number of Q-sorts; however, this would be of little use because then one would be better off "simply examining the original Q-sorts directly" (Brown, 1980, p. 220). Therefore, Brown (1980, p. 220) explained, "factor analysis produces m factors and a matrix n x m, so there is no real condensation of information unless $m < n$, i.e., unless the correlation matrix can be explained in terms of a number of factors that is less than the number of persons involved."

There are a number of approaches to deciding on the number of factors to extract. According to Watts and Stenner (2005) the standard approach is the use of the eigenvalue as a metric for deciding which factors to extract. This is most likely the case for two reasons: the eigenvalue is a quality indicator of a "factor's statistical strength and explanatory power" and the eigenvalue approach, or the Kaiser-Guttman criterion, is generally accepted in the factor analytic community (Watts & Stenner, 2012, p. 105). The eigenvalue is a good indicator of a factor's statistical strength and explanatory power because it is a function of the squared factor loadings, and the squared factor loading for a Q-sort is the variance explained by that particular factor (see Appendix B.7 for a discussion on explained variance). The eigenvalue is expressed as follows (Brown, 1980, p. 222):

$$EV_A = \sum_{w=1}^{W} f_A{}^2$$

where EV_A is the eigenvalue of the factor A, and $\sum_{w=1}^{W} f_A{}^2$ is the sum of the squared factor loadings for factor A across all W Q-sorts. The variance explained equals (Brown, 1980, p. 222):

$$\%\ total\ variance = 100(\frac{EV}{W})$$

Using this method, an investigator would consider any factor to be significant if it had an eigenvalue greater than one. The rationale behind the cutoff point of one has to do with explanatory power, and a factor with a low eigenvalue may have less explanatory power than a single Q-sort (Watts & Stenner, 2005), which obviously defeats the purpose of factor analysis. For example, a factor that has an eigenvalue of 0.5 in a study with 100 participants has a total variance explained of 0.5%, which is less than the 1.0% of total variance explained by a single Q-sort.

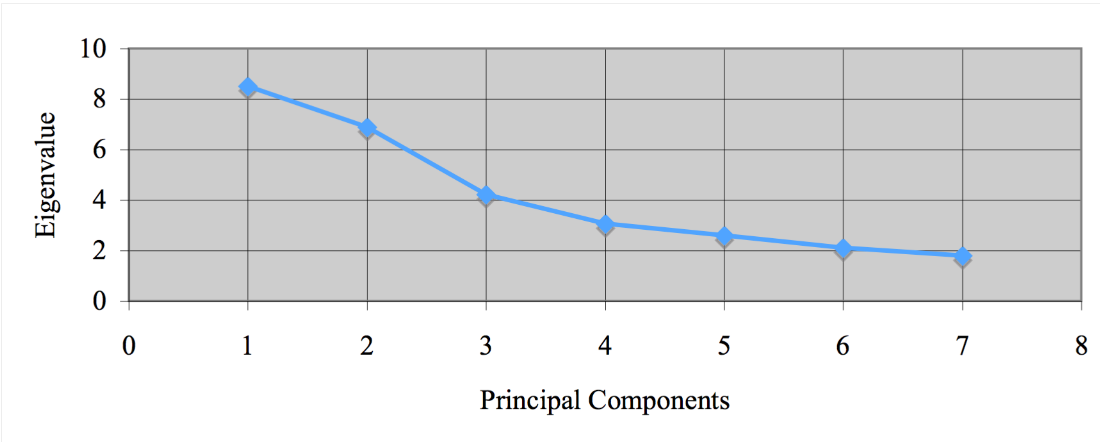
The issue with the eigenvalue approach is the fact that the magnitude of the eigenvalue is directly related to the number of Q-sorts in a study. As a result, a study with a large number of Q-sorts (e.g. 96 in this study of water-based ecosystem services) will yield factors with high eigenvalues, which is not very helpful in identifying those factors that should be extracted because they all may be greater than one.

Application of the EV for a study with a large number of Q-sorts is not as hopeless as it initially appears, however, because the EV can inform the factor-extraction question in an additional way, which will "prevent the arbitrary retention of all factors with EVs greater than 1.00" (Watts & Stenner, 2012, p. 108). Cattell's (1966) scree test can help to inform the factor extraction question when there are several EVs greater than 1.00. An investigator employing the scree test would plot the EVs[9] on graph paper, and then connect all those points with a ruler, resulting in a line graph similar to Figure 4.2.

The investigator would find the point where the slope of the line changes, and extract the factors up to that point. For example, inspection of Figure 4.2 indicates that the slope of the line graph changes at the third principal component and, according to the scree test, this is the number of components to extract. Even though there is more than one point where the slope changes, use of a ruler will show that the major slope change is at the third principal component.

[9] According to Watts and Stenner (2012), the EVs used for the scree test are those that result from PCA, which was the context in which the scree test was designed. Therefore, an investigator using the scree test in Q-methodology would have to run an initial PCA, because the EVs that result from a PCA will differ from those that result from factor analysis. Despite the need to run a PCA, the number of principal components that the scree test indicates should be extracted can be transferred directly to the centroid method. For example, if the scree test indicated that three principal components should be extracted, then three factors should also be extracted using the centroid method.

Figure 4.2 Example of scree test using 7 principal components



Source: Adapted from Watts and Stenner (2012, p. 108).

Another approach is extracting a factor with at least two significant loadings. In order to decide if a factor loading is significant, the investigator can multiply the standard error ($SE_r = \frac{1}{\sqrt{N}}$, where subscript *r* denotes the standard error of the correlation coefficient between two Q-sorts) by 2.58, if using a p level of $p<0.01$. For example, Brown's (1980) Lipset study has an N of 33, which means that the $SE_r=0.17$ and the factor loading needs to be greater than 0.44 to be considered significant at the 1% level of significance.

A different method for deciding which factors should be extracted is Humphrey's rule (Fruchter, 1954, p. 79-80), which stated that a factor is "significant if the cross-product of its two highest loadings (ignoring sign) exceeds twice the standard error, i.e., ($2SE_r$)" (cited in Brown, 1980, p. 223). For the Lipset study, $SE_r=0.17$, and $2SE_r=0.34$. There is also a less stringent version of Humphrey's rule where the cross-product of a factor's two highest loadings must exceed at least one standard error (Brown, 1980, p. 223).

Despite the aforementioned criteria for deciding how many factors to extract, Brown (1980, p. 223) noted, "the range based on statistical criteria appears to be from two to four factors. For purposes of rotation…it is best to take out more factors than it is expected ahead of time will be significant. Experience has indicated that 'the magic number 7' is generally suitable." Watts and Stenner (2012, p. 106) agreed that the use of objective criteria like eigenvalues, total variance and Humphrey's rule are "not the be-all end-all in Q-methodology." According to Watts and Stenner (2012, p. 107), the objective criteria are "helpful parameters, not rules to be obeyed," and their experience has indicated that a good starting point is to extract one factor for every 6-8 participants with a maximum of seven factors extracted initially. Watts and Stenner (2012, p. 197) created the Table 4.5 as a guideline:

Table 4.5 Starting points for factor extraction based on number of Q-sorts

Number of Q-sorts in the study	Number of factors to extract as a starting point
<12	1 or 2
13-18	3
19-24	4
25-30	5
31-36	6
>36	7

Source: Watts and Stenner (2012, p. 197).

In the end, it is the researcher that is required to decide which factors are the most significant, and this can be done both theoretically and statistically (Mckeown & Thomas, 1988). Certain factors will have high statistical significance, which is the purpose of the techniques mentioned above. However, other factors may not have a particularly high statistical significance, but they may be theoretically important. For example, a Q-study done by Brown (1980) discussed a situation where one respondent skewed the results of the fourth factor, which had an eigenvalue of less than one, and was not statistically fit for extraction. However, since that respondent was "the ultimate decision maker on the team, i.e., the person whose views, no matter in how small a minority, always carried the day by dint of his formal authority," the factor was extracted (Brown, 1980, p. 40). In this particular study there were three statistically important factors and one theoretically important factor, and Brown (1980, p. 42) made the point that "the importance of a factor cannot be determined by statistical criteria alone, but must take into account the social and political setting to which the factor is organically connected."

Watts and Stenner (2012) added that the goal of the researcher may ultimately dictate how many factors are to be extracted, and the use of inductive, deductive, or abductive logic by the researcher can be influential to the researcher's goal. For example, if a researcher were doing a Q-study on the approach to wildfire management then a two-factor solution could be explored with the expectation that there would be two main viewpoints: fire suppression and let-it-burn. This would be indicative of a deductive approach, which is similar to hypothesis testing. On the opposite end of the spectrum, an inductive approach would require the researcher to "follow the demands of the data," which is a technique that is associated with exploratory factor analysis (Watts & Stenner, 2012, p. 95). As was previously discussed, in Q-methodology, it may be best to take an abductive approach for an exploratory study.

4.2.5.4 Factor rotation

The third step in factor analysis is factor rotation. The purpose of rotation is to offer a "shift in perspective" (Brown, 1980, p. 226), which in no way "improves the degree of fit between the data and the factor structure" (Kim & Mueller, 1978, p. 50). In other words, factor rotation will change the arrangement of the factor loadings, but it will not alter the overall variance explained or the composition of the original correlation matrix. Factor rotation is a necessary step to achieve the factor analytic goal of identifying and interpreting factors and, as Kline (1994, p. 56) asserted, it is a goal that "unrotated solutions are not useful" in facilitating. The reason that unrotated solutions are not useful for identification and interpretation of factors is due to the original unrotated factor matrix being just one of "almost an infinity of mathematically equivalent set of factors" (Kline, 1994, p. 56).

Kim and Mueller (1978, p. 38, emphasis in original) addressed the difficulty of interpreting unrotated factors by outlining three problems with drawing conclusions about the relationship between the unobserved variables (factors) and the resulting correlation matrix:

> (1) a particular covariance structure can be produced by the same number of common factors but with a *different configuration* of factor loadings; (2) a particular covariance structure can be produced by factor models with *different numbers* of common factors; (3) a particular covariance structure can be produced by a factor analytic causal model as well as a non-factor analytic causal model.

These three problems contribute to an inherent uncertainty that exists in drawing conclusions between the factor structure and the correlation matrix. The first two issues described above are evident during the rotation process, and are actually referred to as problems of rotation (Kim & Mueller, 1978, p. 39). The third issue has to do with the causal structure of a linear relationship, and it is less pertinent in Q-methodology because the observed variables being analyzed are Q-sorts, which are done in a private setting without the influence of another observed variable. Therefore, it doesn't seem possible that the Q-sort of one participant could be caused by the Q-sort of another participant, unless there was collaboration during the Q-sorting process. Kim and Mueller (1978, p. 16) noted that "the notion of covariation is independent of the underlying causal structure; two variables can covary either because one variable is a cause of the other or both variables share at least one common cause, or both." In the case of Q-methodology, the observed variables (Q-sorts) may covary because they *share at least one common cause* (common factor) and not because *one variable is a cause of the other*.

The obvious question that arises from these issues is: how does an investigator know which factor matrix is fit for identification and interpretation? The following point made by Abdi (2003, p. 1) partly answers the question:

> It is important to stress that because the rotation always take place in a subspace (i.e., the space of the retained factors), the choice of this subspace strongly influences the result of the rotation. Therefore, in the practice of rotation in factor analysis, it is strongly recommended to try

several sizes for the subspace of the retained factors in order to assess the robustness of the interpretation of the rotation.

The number of factors chosen for rotation will have an impact on the orientation of the factor loadings, thus changing the meaning of the factors themselves. So, if eight factors are initially extracted, for example, then it is beneficial to try several rotations (i.e. rotate 3, 4, 5, and 6 factors in separate rotations) and compare the results to see which rotation explains the data most appropriately.

There is no definitive rule for deciding which rotation explains the data *most appropriately* but, similar to the question of how many initial factors to extract, there are both theoretical and statistical qualities of a rotated factor matrix that should be considered by an investigator. The theoretical considerations for deciding which rotated factor matrix is suitable are different for each research project, but they are the same as the theoretical considerations discussed at the end of the previous section. An important statistical consideration with regard to the factor matrix is the total amount of explained variance and, as Brown (1980, p. 209) asserted, "an important characteristic of the final set of factors is that they should account for as much of the variability in the original correlation matrix as possible."

Aiming for a simple factor solution is also a recommended statistical guideline for deciding which factor rotation is best. A simple factor solution follows the ideas that stem from the law of parsimony, and it is regularly applied in the natural sciences (Kline, 1994). When considering which rotation is the most appropriate, "it makes sense to pick the most simple solution from the infinity of rotations" (Kline, 1994, p. 65). In order to identify the most-simple solution, the investigator should seek a rotation that most closely resembles the criterion for a simple structure[10] developed by Thurstone (1947 cited in Kline, 1994, p. 65):

1. Each row of the rotated matrix [Table 4.6] should contain at least one zero.
2. In each factor the minimum number of zero loadings should be the number of factors in the rotation.
3. For every pair of factors there should be variables with zero loadings on one and significant loadings on the other.
4. For every pair of factors a large proportion of the loadings should be zero, at least in a matrix with a large number of factors.
5. For every pair of factors there should be only a few variables with significant loadings on both factors.

Table 4.6 Rotated factor matrix

		Rotated Factors		
		1	…	m
Q sorts	1	$f_{1,1}$	…	$f_{1,m}$
	…	…	…	…
	W	$f_{W,1}$		$f_{W,m}$

Note: m is equal to the total number of rotated factors, W is the total number of Q-sorts (people) in the study, and f_{wm} is the factor loading for the wth person on the mth rotated factor.

[10] Thurstone's simple structure is an idealized situation. In practice, there will rarely be any factor loadings with a value of zero, and there will most certainly not be several factor loadings with a value of zero. However, the qualities of the simple structure can serve as guidelines for an investigator to decide if one rotation is better than another.

Simple structure rotation will yield factors that are interpretable and, according to Kline (1994), there is little reason to take non-simple structure results seriously.

Now that both the purpose and idealized solution of rotation have been discussed, it is necessary to outline how rotation is actually completed. There are two main types of rotation: orthogonal rotation and oblique rotation. Oblique rotation allows the new axes to take any position in the factor space (Abdi, 2003) and, as a result, the factors may have some degree of correlation with each other. Even though the degree of correlation between two factors that have been obliquely rotated is small (due to highly correlated factors being merged into one) (Abdi, 2003), this account will focus on orthogonal rotation only, which deals with the rotation of factors to a point of zero correlation. Orthogonal factors are of the greatest interest in Q-methodology, because they are the factors that explain unique perspectives with no overlap.

Factor rotation can be done using statistical routines like varimax (by far the most popular method of rotation (Abdi, 2003)) and quartimax, which rotate the original factors to a "mathematically precise solution" (Brown, 1980, p. 224). Rotation can also be done manually, which is typically the chosen method if the researcher has some theory in mind. This is known as "judgmental rotation," and it "enables the investigator to follow theoretical inclinations" (Brown, 1980, p. 227). This section will include a brief discussion of the process of varimax rotation, but it will not discuss the procedure of judgmental rotation. A description of judgmental rotation in Q-methodology can be found in Brown (1980).

Even though the investigator will not describe the procedure of judgmental (by-hand) rotation, it serves the interest of thoroughness to highlight some of the advantages and disadvantages of the by-hand approach. One advantage of by-hand rotation is the ability of the investigator to focus on viewpoints that may be not be prevalent among the whole group of Q-sorters, but are nonetheless important because they are the "one or two viewpoints that may in reality carry the most substantive weight" (Watts & Stenner, 2012, p. 123). Statistical rotational approaches have difficulty highlighting the minority viewpoints, because they rigidly pursue a solution with the greatest amount of communality. For example, varimax rotation accounts "for as much of the *common* variance in the study as possible" (Watts & Stenner, 2012, p. 123, emphasis in original), which could potentially overlook a small number of Q-sorts that embody an important perspective because they contribute little to the overall common variance of the study.

The commonly discussed disadvantage of by-hand rotation is related to a fear of potential researcher bias. Watts and Stenner (2012, p. 123) explained, "A good number of journals in a good number of disciplines won't accept a factor solution derived in this way [by-hand] because it immediately appears to be subjective and unreliable." Another disadvantage of by-hand rotation, which is practical in nature, is that "it takes time, practice and a decent helping of confidence to take control in the fashion that is demanded" (Watts & Stenner, 2012, p. 124). The first disadvantage discussed is an issue for all Q-methodologists, but the second disadvantage discussed is especially pertinent for an investigator that is new to the method.

Varimax rotation, which is not criticized for being unreliable because of its statistical process, attempts to achieve simple structure while keeping the factor axes orthogonal (Kline, 1994). Again, orthogonal means that "the rotated factors are uncorrelated and the communalities and the ability to reproduce the original correlation matrix are identical to the original factor analysis" (Kline, 1994, p. 68). Abdi (2003, p. 3, emphasis in original) explained that the goal of varimax rotation is to find a linear combination of the original factors "such that the *variance* of the loadings is maximized, which amounts to maximizing" the following:

$$v = \sum (f_{wm}^2 - \overline{f_{wm}^2})^2$$

where f_{wm}^2 is the squared loading of the w$^{\text{th}}$ variable on the m$^{\text{th}}$ factor, and $\overline{f_{wm}^2}$ is the mean of squared loadings. In order to maximize the variance across all factors, "there must be numerous high loadings and small loadings. The extreme case would be where half the variables have loadings of +1.0 or -1.0 and the other half have loadings of zero" (Gorsuch, 1983, p. 185). In the context of Q-methodology, it becomes apparent why a simple structure solution using varimax rotation will yield interpretable factors. A factor that has numerous high loadings and low loadings is a factor that is clearly correlated, or uncorrelated, with certain Q-sorters.

4.2.5.5 Generating factor arrays from factor scores

The next step in factor analysis is the merging of factor scores into factor arrays. In Q-methodology, each factor has a number of Q-sorts (or participants) that load onto it, and it is the merging of those Q-sorts into a factor array that can finally bring meaning to the data. A factor array is a typified Q-sort of all the participants that load onto a particular factor. Before merging the Q-sorts into a factor array, however, "it is necessary to assign a *factor weight* to each as a reflection of the fact that some Q-sorts are closer approximations to a factor than are other Q-sorts" (Brown, 1980, p. 240, emphasis in original). By accounting for the factor weights, it ensures that a Q-sort with a loading of 0.90 on factor A, for example, will contribute to factor array A more than a Q-sort with a loading of 0.65. It is for this reason that factor arrays are typified, and not exact representations of the viewpoints of those that load onto a particular factor. The desired reaction from a participant that is examining the factor array on which they loaded would be: "It is not exactly how I feel, but it is close."

Computing the factor weight is done with the following equation:

$$g = \frac{f}{1 - f^2}$$

where g is the weight, and f is the factor loading. Using Brown's (1980) Lipset study as an example, the following is the weight of subject 6's contribution to factor A.

$$g_6 = 0.82/\ 1 - 0.82^2 = 2.50$$

The weights are then applied to the raw scores for each statement, and are summed across all Q-sorts for that factor, which results in the total score for each statement on each factor, and is represented by K_n:

$$K_n = \sum_{y=1}^{Y} g_y c_y$$

where n is equal to the statement number, Y is the subset of W participants (Q-sorts) that load onto the factor of interest, g is the weight for participant y, and c is the raw score participant y gave for statement n. For example, in Brown's (1980) Lipset study, factor

A is defined by two Q-sorts, participant 6 and 7, which have the respective weights of 2.50 and 1.43. The raw scores for statement 1 for participant 6 and 7 are +1 and +2, respectively, and can be found by inspecting Table 25 in Brown (1980, p. 202). The weights are multiplied by the raw scores and then summed, which results in K_1 for statement 1:

$$K_1 = ((2.50)(+1)) + ((1.43)(+2)) = 5.36$$

This is a process that would happen for all statements (33 in the Lipset study), and all factors. Brown (1980) explained a needed adjustment during this process, "since factors contain differing numbers of subjects producing statement totals of differing magnitudes, it is convenient for purposes of comparability to normalize the total column." Normalizing the total for each statement is done with the following equation, which results in a z score for statement n:

$$z_n = \frac{K_n - \overline{X_K}}{s_K}$$

where K_n is the total value for statement n, $\overline{X_K}$ is the mean of K across all statements ($\overline{X_K} = \frac{\sum_{n=1}^{N} K_n}{N}$), and s_K is the standard deviation of K. The z scores for each statement are then used to build the factor array. The highest two z scores for factor A, for example, would be placed in the highest two spots on the Q-board, and the next three highest scored statements would be in the next three spots on the Q-board, and so on.

The factor arrays are the final product of factor analysis, and each separate array (one for each factor) represents a unique viewpoint with regard to the topic of investigation. On occasion, a factor may be defined by both positive and negative loading Q-sorts, which Watts and Stenner (2012) referred to as "bipolar factors." A bipolar factor is indicative of two viewpoints: the positive viewpoint, which is expressed by the resulting factor array, and the negative viewpoint, which "is the mirror image or direct opposite of that created for the positive viewpoint" (Watts & Stenner, 2012, p. 165). For the sake of interpretation, it is suggested that the investigator create two arrays for a bipolar factor. Watts and Stenner (2012, p. 166) noted that there is nothing "bad or wrong" about the viewpoint of the negative pole and, therefore, when interpreting the opposite array the investigator should be careful to not cast the negative viewpoint in a negative light.

4.2.5.6 Factor interpretation and articulation of results

The final step in a Q-methodological study is the interpretation and articulation of the resulting factors. Factor analysis or PCA (see Appendix B.8 for a short discussion of the difference between factor analysis and PCA) of the covariance matrix is quantitatively done by a computer software program such as PQMethod, which results in a printout of various factor loadings and factor scores. The interpretation of the results, though, is to be completed by the researcher. This section will discuss the end product that is yielded by the computer program PQMethod, the process of interpreting the results, and the write-up of the interpretation.

The factor analysis completed by PQMethod yields three matrices: an "unrotated factor matrix," which shows how all Q-sorters loaded onto each factor extracted from the original correlation matrix; a "cumulative communalities matrix," which illustrates the cumulative variance explained by each unrotated factor for all Q-sorters; and a rotated "factor matrix with an X indicating a defining sort," which exhibits the loadings of every Q-sorter for all rotated factors with an "X" placed next to the loading for the factor that particular sorter has contributed to defining.

In PQMethod, only those Q-sorts indicated by an "X" will contribute to defining the resulting factor array, and the process of assigning an "X" to a factor loading is known as flagging. PQMethod requires that the investigator decide if the rotated factor matrix is to be automatically flagged or manually flagged. The criteria used to decide if a loading is significant and should be flagged, varies. The varying criteria have already been discussed, without use of the PQMethod term "flagging," in Section 4.2.5.3 on the extraction of initial factors. As a reminder, a factor loading can be deemed significant if it is greater than the standard error ($SE_r = \frac{1}{\sqrt{N}}$) multiplied by 2.58, if using a p level of $p<0.01$. If using a p level of $p<0.05$, then multiply the standard error by 1.96.

If flagging manually, the criteria used to decide if a factor loading is significant is at the sole discretion of the investigator, but Watts and Stenner (2012) recommended the use of a p level of $p<0.01$. According to Schmolck (2011b, p. 15), if an investigator employs the automatic flagging option given by PQMethod then all "pure" factor loadings for each Q-sort will be flagged if two requirements are met: (1) $f^2 > \frac{h^2}{2}$, where f is the factor loading and h^2 is the communality; (2) $f > 1.96(SE_r)$. In other words, PQMethod automatically flags *pure* factor loadings if the square of the factor loading is more than half of the common variance and the factor loading is significant at a p level of $p<0.05$. A Q-sort is considered *pure* if it only loads significantly onto one factor. A Q-sort can also be "confounded," which means that it possesses "a significant factor loading in relation to more than one of the study factors" (Watts & Stenner, 2012, p. 129). According to Watts and Stenner (2012, p. 129), confounded Q-sorts are typically "not used in the construction of any of the factor estimates [arrays]." Confounded Q-sorts are not used in the construction of the factor arrays because they are a reflection of at least two factors, which can create overlap between the resulting factor arrays. McKeown et al. (1999) asserted that by excluding the confounded Q-sorts an investigator is able to maximize the difference between factors. Even though the confounded Q-sorts are typically not used to help define the factor arrays, they can still be explained in terms of the resulting factor arrays. Those Q-sorts that are not *pure* or *confounded* are known as "null cases" because they do not load significantly onto any of the extracted factors (Brown, 1980, p. 229).

Another output provided by PQMethod is a table of "correlations between factor scores," and a discussion of this output may help to clarify the concept of confounded Q-sorts. This table shows the correlation (1 to -1) between factor arrays, which is a potential source of confusion because it has been noted that orthogonal rotation creates factors that are zero-correlated and contain no overlap. These previous statements still hold true because the correlation between factor arrays is not a reflection of a correlation between factors. Watts and Stenner (2012, p. 141) explained that the resultant factor arrays are estimates of the factor, which must contain some error. The only time that this would not be true is in the rare event that a Q-sort loads %100 onto a particular factor. Watts and Stenner (2012, p. 141, emphasis in original) clarified by noting that factor arrays are created using Q-sorts "whose position and viewpoint closely approximates that of the relevant factor, but an approximation is not perfection. For this reason, your factor arrays will always *intercorrelate* to some extent, even though the factors themselves are orthogonal and zero-correlated." The inclusion of confounding Q-sorts for the construction of factor arrays would, consequently, increase the correlation between arrays, which is not desirable for the interpretation. Watts and Stenner (2012, p. 141) cautioned that "especially high or significant correlations" between factor arrays is an indication that they may be "too alike to interpret as separate factors and that they could, in fact, simply be alternative manifestations of a single viewpoint." If such a case arises, it is a cue that the researcher may need to reconsider the factor solution, and "perhaps reduce the number of factors" (Watts & Stenner, 2012, p. 141).

In addition to the output described above, PQMethod also calculates the z-scores for each statement across all rotated factors, the differences in z-scores for all statements between each rotated factor (e.g. the difference in the z-score for statement 6 for rotated factor 1 and 2), the Q-sort scores for each statement across all rotated factors, the distinguishing statements for each rotated factor (see Appendix B.9), and a number of factor characteristics (i.e. number of defining variables (Q-sorts that load onto a rotated factor, which are indicated by an "X"), average reliability coefficient (see Appendix B.5), composite reliability (see Appendix B.9), and the standard error of factor z-scores (see Appendix B.9)). PQMethod also indicates those statements that are in consensus among all factors. The "consensus statements" are those that do not statistically distinguish between any set of factors. True to the name, "consensus statements" are those that all factors agree upon, and the agreement can be positive, negative or neutral. Brown (1980, p. 26) asserted that it is important to realize "that consensus need not be based on common understanding." In other words, just because each factor views a statement similarly, it does not mean that each factor has that view for the same reasons.

Q-methodological literature is lacking with regard to a detailed discussion of factor interpretation (Watts & Stenner, 2012), which may be due in part to Brown's (1980, p. 247) assertion that, "there is no set strategy for interpreting a factor structure; it depends fore-most on what the investigator is trying to accomplish." Despite the lack of an interpretation framework, there is agreement that a holistic approach should be adopted when considering the resulting factor arrays. Stephenson (1936) stressed the holistic approach of Q-methodology as a distinguishing characteristic from the atomistic nature of R-methodologies. *Atomistic* refers to the variables in R-methodologies being an aggregate of component parts, which leaves the investigator with the task of "determining what goes with what" (Brown, 1980, p. 14).

In order to maintain a holistic approach, Brown (1980, p. 246) offered the following advice for factor interpretation: "in general…we typically have a greater interest in the more global aspects of the factors." Watts and Stenner (2012, p. 149, emphasis in original) stressed the holistic approach as well, “if factor interpretation is to be carried out thoroughly and in keeping with this methodological holism, the final product really must explain, or otherwise account for, the *entire item configuration* captured in the relevant factor array.” The reason that these Q-methodological experts are offering up such advice is because of the common inclination to focus the interpretation of the factor arrays on either the statistically distinguishable statements or “the limited items that occupy the highest or lowest rankings in a configuration” (Watts & Stenner, 2012, p. 149).

It would not be a mistake for an investigator to pay special attention to the statistically distinguishable statements, which is encouraged by Brown (1980), but it would be a mistake to concentrate solely on those statements. Watts and Stenner (2012) remarked that focusing only on a few items in a factor array is both a methodological and ethical issue. Methodologically it is an issue because concentrating only on a few items is “clearly symptomatic of the by-item or atomistic methods that Stephenson was trying to avoid,” and ethically it is an issue because, if an investigator is not interested in the whole configuration of the Q-set items, then the Q-sorting exercise is a waste of the participants’ time” (Watts & Stenner, 2012, p. 149).

Now that it has been established that a holistic approach to factor interpretation is needed, the task of actual interpretation remains. Watts and Stenner (2012, p. 150) aimed to fill a void in the Q-methodology literature by outlining “a simple system for delivering sound and holistic factor interpretations.”

The interpretive system starts with a "crib sheet," which Watts and Stenner (2012, p. 150, emphasis in original) explained as a way to help to ensure that: factor interpretation is applied consistently to all factors, interpretation is done holistically, nothing obvious gets missed, and a system of organization is in place to force engagement "with *every item* in the factor array." Development of the crib sheet can commence once the rank of each item in the factor arrays is organized, which is exemplified in Table 4.7, where N is the total number of items in the Q-set, m is the total number of factor arrays, and the numbers in the matrix are the scores assigned to each item in their corresponding factor array.

Table 4.7 Starting point for crib sheet

		Factor Arrays			
		F1	F2	…	Fm
Statement number	01	-4	2	1	0
	02	4	2	4	1
	03	-1	0	-1	3
	…	…	…	…	…
	N	1	0	3	-3

The crib sheet contains four categories, and a crib sheet is completed for each factor array. The four categories are: (1) Statements with the highest rank (+4 for the Q-board in Figure 4.1), (2) statements ranked higher in the factor array being inspected than in all other factor arrays, (3) statements ranked lower in the factor array being inspected than in all other factor arrays, (4) statements with the lowest rank (-4 for the Q-board in Figure 4.1).

Using Table 4.7 as an example, the crib sheet for factor array 1 (F1) would include statement 1 in the category *statements with the lowest rank*, and statement 2 would fit in the category *statements with the highest rank.* In the case of a tie, which is the situation for statement 3 in the category of *statements ranked lower in the factor array being inspected than in all other factor arrays,* Watts and Stenner (2012, p. 153) stated that inclusion or exclusion is a "matter of taste, although trial and error has led us to prefer their inclusion." Statement N would not fit in any category and, therefore, would be left out of the crib sheet for factor array 1.

By applying the crib sheet method, Watts and Stenner (2012) suggested that it may be easier to find statements of meaning that occupy the middle of the distribution. There is a tendency to assume that the middle values on the ranking distribution are "indicative of neutrality, total indifference or a general lack of significance or meaning. This assumption will often be correct, but on occasion a [statement] sitting right in the middle of the distribution can act as a fulcrum for the whole viewpoint being expressed" (Watts & Stenner, 2012, p. 155). The authors described a previous study where a statement scored as 0 in one factor array was found to be important because of its relative ranking in the rest of the factor arrays. A point that led Watts and Stenner (2005, p. 155, emphasis in original) to conclude that even though most "near-zero rankings won't prove to be crucial or pivotal…the ones that are *must* be identified. Application of the crib sheet method guarantees your attention will be drawn to any likely candidates." Stevenson (1974, p. 11) also made the point that the statements ranked at zero are not to be ignored, because he felt that the "subject is apt to place statements at zero about which he or she is defensive. Some of the most telling data come from statements hidden away in this manner."

Once the crib sheet is complete, Watts and Stenner (2012) suggested that the investigator apply the logic of abduction to build a story about each factor array. This requires that attention be paid to every statement, and the implications of each individual statement's position on the crib sheet to the wider viewpoint must be considered. Watts and Stenner (2012, p. 156, emphasis in original) instructed, "your attention must continually *oscillate* between the individual items, on the one hand, and the whole story or viewpoint, on the other." Once a story starts to develop, it is time to incorporate the collected demographic data, which is data that could have been addressed prior to factor interpretation. However, by waiting to use the demographic data, the investigator "ensures that each factor array is approached *on its own terms* and it also prevents our succumbing to the temptations of preconception and expectation" (Watts & Stenner, 2012, p. 157, emphasis in original). The last step of the interpretation of the factor arrays, prior to the write-up exercise, is final review of the statements that were not included on the crib sheet with the aim of including any statements that may be potentially useful.

The write-up exercise is meant to convey the meaning of each factor. Each factor is named, which provides an identity for the factor and makes it more memorable for the reader (Watts & Stenner, 2012). The description of each factor should start with relevant statistical and demographic data. Watts and Stenner (2012, p. 162) stressed the narrative style of the interpretation, and its reference to all items that are included on the crib sheet. However, the narrative approach is not the only style or most correct style of interpretation. There is also the commentary approach, which "involves the wording of each relevant item being cited in full and the weaving of an interpretative commentary around those citations" (Watts & Stenner, 2012, p. 162). Regardless of the writing style chosen for interpretation, Watts and Stenner (2012, p. 162) suggested that it is best to have the commentary build in momentum, and not to include the high and low ranking statements first, but to "let them find their rightful place within the overall account." Another option for the write-up exercise is the use of qualitative comments made by participants that loaded significantly onto the factors. Watts and Stenner (2012, p. 163, emphasis in original) end their discussion of this topic with the following:

> In the end, effective factor interpretation will follow if you have a power desire to do justice to the viewpoint in question and to the participants who produced it. The interpretation must *express* what was *impressed* into the array. Working thoroughly, systematically and attending to the whole item configuration are also very important.

As a last line of defense for any doubt an investigator may have about their interpretation and subsequent write-up, Watts and Stenner (2012) noted that consulting one or two participants that loaded onto the factor in question could be helpful.

4.3 Evaluation of Alternative Stakeholder Preference Elicitation Methods

There are several stakeholder preference elicitation methods that could improve understanding of the importance of water-based ecosystem services derived from the SNF. This section will briefly describe five approaches: one case study, three non-monetary methods, and one monetary approach. The non-monetary approaches are the decision-analytic methodology, analytic hierarchy process (AHP), and survey research using the Likert scale to elicit preferences. The monetary approach to be discussed is contingent valuation (CV). This section will briefly review these methods with the aim of illustrating why Q-methodology will complete the objectives of this study most effectively. This section is not a critique of these other methods, and it does not imply that Q-methodology would have better served the purposes of other studies. Simply, the investigator would like to point out why Q-methodology was chosen in the context of this study, as opposed to other potential methods.

A reminder of two of the research objectives for this project may be helpful in order to effectively highlight the contrast between Q-methodology and the other methods to be discussed in this section: (1) identify the full range of water-based ecosystem services being derived from the Shoshone National Forest; and (2) understand the full range of stakeholder[11] perspectives regarding the importance of water-based ecosystem services being derived from the Shoshone National Forest. The *full range* aspect of both objectives is of paramount importance and, as a result, the investigator was focused on collecting the diversity of stakeholder perspectives, as opposed to a representation of

[11] Stakeholder participation is integral to the understanding of societal preference and, within the context of this study on water-based ecosystem services, stakeholders are defined as any person, group of persons, or entity with "interest or stake in a particular issue or system" (Grimble & Wellard, 1997, p. 175).

societal viewpoints. In other words, the result of this study aspires to present the gamut of viewpoints that may exist, and not the prevalence of any particular viewpoint.

4.3.1 Case study example that employed random sampling

Identifying and involving stakeholders is a difficult process, but if done successfully, the rewards are great. Stein et al. (1999, p. 400) asserted that better identification and articulation of the "hard-to-define" benefits provided by natural systems improves the ability of natural resource managers to include those benefits in their management planning. Their case study in the Red River Basin in the Upper Midwest of the United States aimed to understand the *hard-to-define* benefits using a two-pronged approach. The first phase consisted of focus groups, and was qualitative in nature. The focus group participants were randomly selected, presumably to combat researcher bias. By using focus groups, the researchers were able to identify perceptions and values held by the local stakeholders. This information was used to create a questionnaire for a second phase.

The use of focus groups to inform the subsequent questionnaire in this case study is laudable, however, the reliance on random sampling to construct the focus groups is concerning because it may have inadvertently left out a number of stakeholders and their important values, which consequently would not have been included in the questionnaire used in phase two. Q-methodology will use purposeful sampling during all phases of the project with the objective of including all stakeholder groups, which will increase the probability of obtaining a more complete range of perspectives related to the topic of interest.

4.3.2 Decision-analytic methodology

Another approach to understanding the perspectives of stakeholders is the decision-analytic methodology, and Martin et al. (2000, p. 22) suggested this approach has "the benefit of measuring consumer preferences in non-monetary terms." This approach could be used in any situation where stakeholder preference is desired; however, these authors use it as a means to identify the preferred alternatives among stakeholders for the development of minerals on the San Juan National Forest. The management alternatives in this case were developed from interviews with stakeholders during the early stages of the study. Preference for the management alternatives were elicited using a rank ordering exercise and, as Martin et al. (2000, p. 23) explained, "ordinal preferences are solicited from each stakeholder over the hypothetical alternative management scenarios as well as the attributes." This study included six alternatives and four attributes for each alternative. The four attributes ranked were: acres available for leasable development, watershed improvement in acres annually, recreational visitor days, and species protection.

In this case, the use of decision-analytic methodology was appropriate because stakeholders were only required to rank six alternatives and four attributes (10 total items), which seems to be a reasonable expectation of the participant. The concern with the decision-analytic method, in the context of the SNF study, is the burden that the ranking exercise may place on the participants, which would require the participant to show their ordinal preference for 34 different water-based ecosystem services. Even though Q-methodology does require the rank ordering of different items, the items are ranked into seven groups from most unimportant to most important, as opposed to ranking from one to thirty-four. As a result, the researcher feels that the rank ordering exercise in Q-methodology is less strenuous while still providing information about the relative importance of the various water-based ecosystem services.

4.3.3 Analytic hierarchy process

Another non-monetary valuation method used in the management of natural resources is AHP. Ananda and Herath (2003) discussed the applicability of this method for understanding societal preferences in the context of forest decision-making. AHP requires the participant to make pairwise comparisons between all items being studied. When making the comparisons, it is both a question of which item is more important and the magnitude of difference in importance (Ananda & Herath, 2003). For example, a participant in this study would provide their ordinal preference for all ecosystem services (34 of them), and indicate the intensity of the relative importance on a scale from one to nine. According to Saaty (1977 cited in Ananda & Herath, 2003), a value of one given in a comparison indicates that the two items are of "equal importance," and a value of nine indicates that one item is of "absolute importance" over the other. The researcher feels that completing this task for 34 items would be both time consuming and cognitively burdensome for the participant. Q-methodology is not interested in the participant assigning a magnitude of difference between the items being ranked and, as a result, it is less burdensome on the participant.

The second reason that AHP may not be appropriate for this study is its approach to stakeholder involvement. According to Ananda and Herath (2003, p. 18), AHP requires that "all significant and key stakeholders must be selected to carry out a comprehensive analysis." However, including a large number of stakeholder groups when using AHP can be a challenge, because it becomes "difficult to draw the line between a major and minor stakeholder" (Ananda & Herath, 2003, p. 18), which is necessary in AHP because the data analysis process weights the various stakeholder groups differently. As a result, certain groups are more influential than others and small-scale resource users are often neglected. According to Grimble and Wellard (1997, p. 176), their relatively small stake should not be sacrificed to the preference of "policy-makers, planners and administrators in government or other organizations, commercial bodies, and more nebulous categories such as 'future generation', the 'national interest' and 'wider society'."

There is a stakeholder-related concern associated with AHP because of its different weighting of stakeholders via its focus on significant, key, major, and minor stakeholders. These methodological attributes are less important for this Q-study because of its exploratory nature. Q-methodology is best at "suggesting a pattern of common or different viewpoints related to certain demographic characteristics because [it] is intended to identify subjectivities that exist, not determine how those subjectivities are distributed across a population" (Brown et al., 1999, p. 602). Even though the inclusion of all stakeholder groups may be impossible, the aim of Q-methodology is to understand the full range of perspectives related to a discourse, and not those that are the most popular. Therefore, “the fact that there is a person who is assumed to have a different point of view is enough reason to include him or her in the sample” (Cuppen et al., 2010, p. 581).

4.3.4 Likert-scale survey research

Survey research is another potential approach for eliciting stakeholder preferences with regard to water-based ecosystem services. A survey that uses the Likert scale approach would require the participants to decide the importance of each water-based ecosystem service on a scale from least important to most important.

The rationale for not employing this method in the SNF study is to avoid the opportunity for the participant to rank each item independently, which is not desirable for the ranking of water-based ecosystem services due to their interdependence. For example, using a Likert-survey instrument as described above would allow a stakeholder to assign the “most important” value to all 34 water-based ecosystem services, which is an unrealistic viewpoint considering the competing nature of many water-based ecosystem services. In addition, the scarce nature of water resources in the study area requires that land managers consider tradeoffs when making decisions. Therefore, a survey that does not force stakeholders to consider tradeoffs would be relatively unhelpful for land managers. This is especially important in the context of this study, because the water-based ecosystem services being ranked are, at times, competing. For example, in-stream flow and commercial irrigation are two water-based ecosystem services that are difficult to manage for because the availability of one service directly affects the availability of the other. Q-methodology requires the participants to make trade-offs between the various services being ranked.

4.3.5 Contingent valuation method

The contingent valuation (CV) method is an often relied upon technique for the valuation of ecosystem services that are not represented in traditional markets (Ananda & Herath, 2003). It can be problematic to simply ask stakeholders, "what are you willing to pay (WTP)" for the preservation or improvement of an ecosystem service? When considering private goods, the preference of the consumer is individualistic and cannot be contended. However, this changes when an ecosystem is in question. Jacobs (1997, p. 213) asserted, "within their preferences, people may include concern for other people, for future generations, for distributional justice, for the intrinsic value of nature, and even concern for the common good (expressed as existence values)." The question of WTP puts a consumer into a self-interested mindset, which is the right mindset when a private good is in question, however, it is inappropriate when dealing with a public good that exists in an environment that lacks a specific market (Jacobs, 1997). The use of CV in the context of this study is inappropriate because of the need to value so many ecosystem services. Requiring the participant to decide their WTP for 34 ecosystem services would be time consuming and strenuous. Additionally, the analysis and valuation process required by the investigator would also require a great deal of time and resources. Q-methodology will assist the researcher in understanding which water-based ecosystem services are important to stakeholders without requiring an unreasonable amount of time and money.

CV could then be employed to value a small number of important water-based ecosystem services.

The modification of the traditional CV method with a ‘voting’ format can place participants in a mindset where they are forced to consider the costs of public policy decisions. The voting format is used to understand the different packages that participants favor. For example, a package could include a management plan that has implications for a number of different ecosystem services. The issue here is the lumping together of a “whole range of costs and benefits” (Jacobs, 1997, p. 219). By lumping services together in a package it becomes difficult to differentiate the individual values of the services for cost-benefit analysis (CBA), which seems to eliminate the main objective of CV (Jacobs, 1997).

Another concern with the use of the CV method for the SNF study that is ameliorated by the use of Q-methodology is the lumping together of attributes into packages, and then having participants express their preferences for those different packages. This approach makes the understanding of the importance of specific items difficult. For example, in the context of the SNF study the CV method may ask participants to decide their WTP for two hypothetical situations, A and B. Where situation A preserves one set of water-based ecosystem services, and situation B preserves a different set of water-based ecosystem services. Q-methodology, on the other hand, is asking participants to indicate which specific water-based ecosystem services are important to them. This approach is more appropriate for the SNF study because it will provide a picture of the importance of various water-based ecosystem services in the study area; an outcome that will more effectively facilitate future phases of this research project.

4.4 Summary

Q-methodology can be employed when the goal of the researcher is to understand the full range of perspectives regarding a topic of interest. There is a wide range of disciplines, outside of its original application within the field of psychology, that have utilized Q-methodology. Q-methodology's focus on the understanding of subjectivity has resulted in it being considered a qualitative research method, however, because of its use of statistics for analysis, Q-methodology is more of a hybrid of qualitative and quantitative methods that was dubbed "qualiquantological" by Stenner and Stainton Rogers (2004).

The procedure of Q-methodology requires that the investigator, with the help of potential participants, articulate the gamut of sentiments (Q-set) related to the topic of interest. The Q-set is then organized via a ranking exercise onto the Q-board (Figure 4.1) as a way to gain the perspective of a participant in reference to the question posed with regard to the topic of interest. The use of purposive sampling by the researcher facilitates the inclusion of as many different perspectives of participants (P-set) as possible for the Q-sorting exercise. The result of the ranking exercise is the Q-sort, which is the unit of analysis in Q-methodology. The Q-sorts are usually analyzed using factor analysis, but the use of PCA is also an option. Factor analysis is a data reduction method that aims to explain all the Q-sorts with a smaller number of factors. The factors are typified Q-sorts that convey a unique and prevalent perspective among the P-set.

Q-methodology is being used for this study because of its ability to provide a nuanced snapshot of perspectives regarding the topic of important water-based ecosystem services. Q-methodology was chosen, instead of other potential methods, because stakeholders are involved throughout the majority of the process, participants are required to consider trade-offs between various water-based ecosystem services, and they are not overly burdened by the data collection process.

Chapter 5

Application of Q-Methodology for Elicitation of Stakeholders' Preferences for Water-based Ecosystem Services Derived from the Shoshone National Forest

Q-methodology was chosen for this study because of its ability to highlight the shared views of stakeholders with regard to the importance of water-based ecosystem services derived from the Shoshone National Forest (SNF). This chapter explains how Q-methodology was used to elicit the preferences from stakeholders with regard to the full range of water-based ecosystem services being received from the SNF. Using Q-methodology, this study was completed in four major phases: (1) concourse, Q-set and Q-board development; (2) P-set development; (3) administration of surveys; and (4) data analysis. This chapter will describe the four major phases in detail in the order presented above. However, it is important to mention that the phases were not completed like four quarters in a basketball game. Steps one and two took place concurrently because, as was mentioned in the previous chapter, the construction of the P-set and the Q-set often occur together. Step three was completed before moving onto step four.

5.1 Concourse, Q-Set and Q-board Development

The development of the concourse was primarily done through a review of ecosystem services literature and study area specific water and climate change research, but the use of focus groups and Forest Service meetings was also employed to supplement and confirm the findings in the literature review. Finalization of the Q-set was a process that was facilitated by pilot testing. Once the investigator was satisfied with the Q-set, the construction of the Q-board commenced. This section will describe how the concourse was constructed, and the process of shaping the concourse into the Q-set. The logic behind Q-board construction will also be outlined.

In order to develop the concourse and Q-set (presented in Section 6.1), which were composed of water-based ecosystem services derived from the SNF, the investigator was required to establish some criteria for what exactly constituted a water-based ecosystem service. The criteria used for deciding how the concourse and Q-set were developed will be discussed in Section 5.1.1. The second subsection will outline the initial stages of the concourse and Q-set development, which involved a literature review of both ecosystem services literature and study-area specific literature. The third subsection will explain the contributions of the focus groups to the concourse and Q-set, and Section 5.1.4 will describe how informal discussions and pilot tests contributed to the finalization of the Q-set.

5.1.1 Criteria for development of the concourse and Q-set

The development of the concourse and Q-set required the investigator to establish some criteria, which could be used as guidelines for deciding what benefits being derived from the water resources in the study area constituted water-based ecosystem services in the context of this project. The investigator created four criteria: *naturalness criterion, blue-water criterion, management criterion,* and *conflict criterion.* Establishment of the aforementioned criteria was the result of considering the following three questions: (1) what is "natural enough" to constitute an ecosystem service?; (2) what ecosystem services are water-based?; and (3) how specific should each water-based ecosystem service be?

It is important to stress that the criteria to be described below were used as guidelines for the development of the Q-set, which means that there is an inherent flexibility in the process of deciding what, in the context of this project, is meant by water-based ecosystem service. In other words, each water-based ecosystem service in the Q-set was not required to meet each criterion. The criteria were used in conjunction with the classification frameworks presented in Section 2.1, and were typically employed in situations that were inadequately covered by the scholarly literature. Therefore, there are certain water-based ecosystem services included in the Q-set that fall outside of some of the guidelines established below, but were included because of other considerations (e.g. economic contribution of an ecosystem service) or were discussed in the ecosystem services literature.

Section 2.1 presented the definition of ecosystem services as "the benefits human populations derive, directly or indirectly, from ecosystem functions," and ecosystem functions were defined as "the habitat, biological or system properties or processes of ecosystems" (Costanza et al., 1997, p. 253). Bateman et al. (2010, p. 6) noted that some of the benefits "come straight from the natural world without the intervention of humans", which implies that some ecosystem services require human intervention prior to the delivery of those benefits to humans. For example, the relief from the summer heat provided by a swim in a cool river is a benefit that requires no human intervention, but the water used to take a bath in the household requires a number of human interventions between the stream, aquifer, or reservoir and the bathtub. The definition for ecosystem service given above, accounts for the human intervention aspect with the use of the phrase *directly or indirectly*. However, there are examples within the context of this project that challenged the investigator to decide if an ecosystem service was, in fact, an ecosystem service when considering the level of human intervention. For instance, the benefit of flood control within the study area is provided by natural systems like wetlands and forests. But floods are also controlled, perhaps to a greater extent, by man-made reservoirs. The final Q-set for this project considered *household/municipal use* of water as an ecosystem service despite the human intervention, but only the flood control provided by natural systems (i.e. not by human-made reservoirs) was regarded to be an ecosystem service. The rationale for distinguishing between these two types of human intervention will be explained below.

5.1.1.1 Naturalness criterion

The investigator developed the *naturalness criterion* as a guiding principal for deciding the acceptable level of human intervention for inclusion of certain water-based ecosystem services in the Q-set. In order for a benefit to be considered an ecosystem service using the naturalness criterion, the benefit had to primarily result from the resource, and not the human intervention. In the context of this project, consider the following three examples as clarification.

(1) Household/municipal use was included in the Q-set as a water-based ecosystem service because, even though modern systems of purification and transport of

water are used in the delivery of water for household and municipal use, they are not necessarily required. In other words, humans survived for a long time by fetching their own water, without the assistance of modern technology.

(2) Flood control in the context of this project only includes that provided by natural systems because, without the use of human intervention (i.e. human-made dams and the resulting storage facilities), flood control that is not provided by natural systems would not be possible.

(3) Benefits directly provided, or facilitated, by man-made reservoirs (e.g. *lake, reservoir, and river-based hunting*) are considered ecosystem services for this project because, even though reservoir-based hunting would not exist without the human-made dam, the benefit is derived from the water and its ecosystem, which just happens to be in a human-made storage facility.

The ecosystem services entitled *hydropower* and *oil and natural gas extraction, and mining*, are two water-based ecosystem services that were included in the Q-set despite their failure to meet the naturalness criterion. The reasons for the inclusion of these two ecosystem services are two-fold: first and foremost, Table 2.1 taken from de Groot et al. (2002, p. 396) established that the ecosystem function of water supply provides goods and services such as "drinking, irrigation, and industrial use." The investigator interpreted the phrase *industrial use* to include *hydropower, oil and natural gas extraction, and mining,* and *manufacturing and industrial use*. Secondly, the large contribution of hydropower, oil and natural gas extraction, and mining to the economy of the study area was an indication that the two ecosystem services should be included in the Q-set.

5.1.1.2 Blue-water criterion

Deciding which ecosystem services were *water-based* required a definition of water-based. Within the context of this project, a water-based ecosystem service has been defined as any ecosystem service that relied on or interacted[12] with "a liquid component in rivers and aquifers" (Rockström et al., 2009, p. 2). The concepts of blue water and green water resources can clarify what is meant by water-based for this project. According to Rockström et al. (2009, p. 2), "green water refers to naturally infiltrated rain, attached to soil particles and accessible to roots. Blue water refers to liquid water in rivers and aquifers." The investigator adopted the blue-water definition for this project, but would slightly modify the definition for blue water to include the liquid water in lakes, ponds, wetlands, and all natural above ground containers of liquid water.

To illustrate the importance of the *blue-water criterion* for the purposes of building the concourse and Q-set for this project, consider an ecosystem service such as carbon sequestration, which is provided by healthy forests, but a healthy forest does not exist without water. Therefore, it could be said that carbon sequestration is a water-based ecosystem service. However, for this project, carbon sequestration was not included because it is supported by green water. An ecosystem service that makes the distinction between blue water and green water more difficult is natural flood control, which is an

[12] The word "interacted" is used because there are certain water-based ecosystem services (e.g. oil and natural gas extraction, and natural flood control) that do not rely on the water per se but, more accurately, interact with the water.

ecosystem service that relies on a high level of vegetation and permeable soil. Healthy vegetation and permeable soil are the results of green water; however, a lack of natural flood control will result in more blue water running off into streams and lakes. Therefore, this project considers natural flood control to be a water-based ecosystem service that *interacts* with blue water.

5.1.1.3 Management criterion

The third question regarding the specificity of each water-based ecosystem service is in reference to the lumping or splitting of certain types of ecosystem services. For example, recreation is an ecosystem service that can be broadly interpreted as any type of recreation that is supported by natural systems. The challenge for the investigator during this project was deciding on the level of specificity for ecosystem services like recreation. The nature of this project narrowed recreation to include only those types of recreational activities that rely on or interact with blue water; however, water-based recreation was still too broad to include as a single ecosystem service in the Q-set. On the other hand, there was an issue of being too specific by breaking water-based recreation into separate services for all water-based recreational activities. In other words, it was not productive to include separate Q-set statements for kayaking, rafting, canoeing, and tubing. Consequently, the investigator had to find the right balance between being too specific and being too broad.

The investigator used two criteria as a means to find the right balance between broadness and specificity of ecosystem services: (1) the capacity for different types of management; and (2) the potential for conflicting sentiments within the same statement. The first criterion, hereafter referred to as the *management criterion*, can be exemplified by the separation of ice and snow based recreation into *motorized* and *non-motorized.* The tendency of land-management agencies to dictate their management approaches around the two different styles of ice and snow based recreation provided good reasoning to include a separate ecosystem service for each type of recreation. The rationale for using the management criterion is attributed to the ultimate goal of this project and its subsequent phases, which is to create a decision-support tool for land managers on the SNF. Therefore, it is prudent to supply land managers with information that is specific and without ambiguity. For example, if the results of this project found that *ice and snow based recreation* was an important ecosystem service, which warranted special attention in future phases, but the investigator failed to separate the *motorized* and *non-motorized* aspects of the activity, then land managers would be left with the impossible task of deciding if they should manage for increased motorized opportunities or increased non-motorized opportunities. Use of the management criterion was meant to create statements that would yield results that are beneficial to land managers.

5.1.1.4 Conflict criterion

The second criterion used for deciding the specificity of each water-based ecosystem service was with regard to the potential for disparate preferences within an ecosystem service. An undesirable statement from a Q-sorter would be, “I am having trouble ranking this statement because I find the first part to be important, but not the second.” This is because interpretation of preferences would be challenging if Q-sorters have trouble ranking a statement because they find part of the statement important, but not the other. For example, the division of irrigation into *personal* and *commercial* was motivated by the possibility that a Q-sorter might feel that the need for water for filling their pond (*personal irrigation*) is not important, when compared to the need for water to irrigate crops for sale on the market (*commercial irrigation*). This consideration highlights the need for each statement in the Q-set to be as conflict-free as possible, which will henceforth be known as the *conflict criterion*.

5.1.2 Development of the concourse and Q-set via literature review

The development of the concourse and Q-set involved the identification and definition of specific ecosystem-services derived from the SNF, which was a process facilitated by a review of ecosystem services literature. The scholarly literature consulted was reviewed in Section 2.1. Specifically, Table 2.1 and the classification and value frameworks discussed in Section 2.1 provided the investigator with general guidelines for constructing a concourse and Q-set that included the full range of water-based ecosystem services derived from the SNF. The information provided by Table 2.1 was only helpful to a point, because it included all ecosystem services (not just water-based), and it too-broadly defined many ecosystem services for the purposes of this project (e.g. recreation). As a result, the use of the four criteria outlined above (naturalness criterion, blue-water criterion, management criterion, and conflict criterion) were employed by the investigator to develop a Q-set that was relevant to the study area and potentially beneficial to land managers.

Reviewing the scholarly literature highlighted certain ecosystem services, such as *in-stream flow, household/municipal water, cultural and spiritual values, artistic and aesthetic values,* and *education*, which were appropriate for the concourse for this project, but were not necessarily unique to the study area. In other words, *in-stream flow* and *household/municipal water* are ecosystem services that are provided by many National Forests in mountainous regions. Therefore, a review of the study-area specific literature was required to identify and articulate water-based ecosystem services that were pertinent to the SNF. For instance, a report entitled *Wind-Bighorn Basin Plan Update* provided useful study-area information, which outlined a "perspective on water resources" for the Wind-Bighorn Basin (Basin) (MWH, 2010, p.1). The report included physical information, economic and social conditions, current uses of water, information on the allocation of the Basin's total water supply, estimates of future water needs, and information on the availability (or lack thereof) of water (MWH, 2010).

The information gleaned from this report (presented in Chapter 3 on research setting) helped the investigator to understand how water was being used in the study area, which ensured that the water-based ecosystem services composing the Q-set were locally relevant and accurate. For example, it is well-known that the study area is a bustling center of oil and natural gas extraction, but the addition of the term *mining* to the title of the ecosystem service *oil and natural gas extraction, and mining* was the result of learning from MWH (2010) that coal, bentonite, uranium and gypsum were being mined in the study area, which are processes that utilize water.

Thorough knowledge of the study area also assisted the researcher in developing the Q-set to include *glacier-based services, hydropower, fighting forest fires, facilitation of land-based recreation, water for stock* and *physically and mentally challenging recreation*. The appropriateness of including an ecosystem service related to glaciers was affirmed by the scholarly literature (presented in Section 3.4.1.4) that has been devoted to monitoring the state of the glaciers within the SNF. The large capacity for generation of hydropower, and the frequency of forest fires in the study area clearly indicated that both uses of water were water-based ecosystem services. Even though the amount of water used for activities such as golf and skiing are nominal in comparison to the water being consumed for agriculture, the focus of this project on identifying the full range of water-based ecosystem services being derived from the SNF warranted the inclusion of *facilitation of land-based recreation.*

Including an ecosystem service for physically and mentally challenging recreation presented a unique decision, because almost any recreational activity can be physically and mentally challenging to the participant. Therefore, this ecosystem service could be viewed as overlapping the other recreation-based ecosystem services in the Q-set. However, the study area provides world-renowned opportunities for physically and mentally challenging recreation. One example is the highly challenging kayak trip through The Box section of the Clarks Fork of the Yellowstone River, which is a trip that draws kayakers from around the world to test their kayak and survival skills. The second, and perhaps better, example of the study area being an exceptionally challenging recreational environment is reflected by the headquarters of the National Outdoor Leadership School (NOLS) being located in Lander, WY.

5.1.3 Development of the concourse and Q-set via focus groups

The use of focus groups was invaluable for the development of the concourse and Q-set because, they served as a way to bring more insight and ideas into the project, and confirm the initial findings of the investigator's literature review.

Two focus groups were organized for Cody, WY and Riverton, WY on December 14th, 2011 and December 15th, 2011, respectively. All participants involved were stakeholders interested in water-based ecosystem services flowing from the SNF. The comprehensive list of the interests represented at each focus group is shown in Table 5.1.

Table 5.1 Interests represented at focus groups

Cody, Wyoming	Riverton, Wyoming
Whitewater Rafting Outfitters	Department of Environmental Quality
Greater Yellowstone Coalition	Wyoming Game and Fish
Fly Fishing Outfitter	Cooperative Extension Services
BLM Recreation	Fish and Wildlife Service
Forest Service Archeology	Wyoming Outdoor Council
Forest Service Hydrology	Local Conservation District
State Engineers Office	Local Rancher
Irrigation District Management	Local Farmer and Livestock Feeder
Guest Ranch Owner	
Trout Unlimited	

By design, both focus groups were comprised of a wide variety of stakeholder perspectives, and the decision regarding which water-interested participants to invite to the focus groups was mainly driven by the list of 23 water-based ecosystem services (see

Appendix C for the concourse) that was developed via literature review. For example, the *cultural and spiritual values* that are derived from water is a topic familiar to those in the field of archeology, which prompted the investigator to extend an invitation to an archeologist. Similarly, the water-based ecosystem services related to *irrigation* are well-known to ranchers and farmers and, as a result, the investigator felt it was necessary to include the perspective of a rancher and a farmer in the focus groups. In both focus groups, there was not an overwhelming presence of any one type of stakeholder. For example, several state agencies were targeted as potential stakeholders, such as the Wyoming Department of Environmental Quality, Wyoming Department of Agriculture, Wyoming Water Development Commission, State Engineers Office, Conservation Districts, and Wyoming Game and Fish Department. There was a feeling that these stakeholders should not all be present at the same focus group because of the chance that other stakeholders would feel uncomfortable and not contribute their own ideas.

Each focus group took place in a Holiday Inn Board Room from 6:00 PM to 8:30 PM. The first half hour consisted of introductions between all people present, ordering of dinner, and a short Powerpoint presentation that outlined both the objectives of the research project and the focus group. Each participant was provided with scrap paper and pen, focus group rules (Appendix D), and the preliminary list of stakeholders. The remaining two hours, which were audio recorded, were used to complete two objectives: identify and define water-based ecosystem services derived from the SNF, and expand the preliminary list of stakeholders.

The primary objective of the focus groups was to identify and define as many water-based ecosystem services derived from the SNF as possible. At the time of the focus groups, the investigator had already constructed a list of water-based ecosystem services (the concourse) derived from the SNF via literature review. However, this list was not presented to the focus group participants because the investigator felt that the list of articulated water benefits would inhibit the thought process, and result in "tunnel vision", making it difficult to think of benefits that were not on the list. Also, the results of the focus groups could potentially serve as a confirmation of the findings of the investigator's literature review.

The participants were instructed to write down on their scrap paper three water-based ecosystem services derived from the SNF. After a few minutes, the investigator randomly chose a participant to voice one of the benefits that they had written down. Once a benefit was stated, the entire group was encouraged to discuss the definition of that benefit. For example, if one participant stated that irrigation was a benefit of the water provided by the SNF, then it was a task of the whole group to define that benefit.

5.1.4 Finalization of the Q-set via informal discussions and pilot tests

The process of finalizing the Q-set included informal discussions with certain stakeholder groups that were not included in the focus group sessions, and pilot tests of the Q-sorting process with one stakeholder and several professors and graduate students from The University of Montana.

Despite the effort of the researcher to include the full range of perspectives at the focus groups, there were two interest groups that were not present. The perspective of the three Native American Tribes within the study area, and the oil and gas industry were not represented at either of the focus groups. The perspectives of the Native American Tribes was excluded from the two focus groups because of logistical obstacles, mainly the need for the approval of the tribal review boards prior to any participation by tribal members. Despite this hurdle, the perspective of the Tribes was collected. The input of members of the Crow Indian Tribe was collected during a group discussion with an environmental committee interested in water. Input of a member of the Northern Arapaho Tribe was collected during a pilot test on the Wind River Reservation. The perspective of an Eastern Shoshone Tribal member was collected during two separate phone conversations.

Exclusion of the oil and gas industry at the focus groups was a result of both scheduling conflicts, and a general defensiveness on the part of administrative assistants of oil and gas companies. It was not uncommon for the investigator to be tersely dismissed by administrative assistants because of the perception that the investigator was interested in proprietary information. On the few occasions where the researcher was able to reach a potential focus group participant from the oil and gas industry there were scheduling conflicts. Despite these difficulties, the investigator was able to arrange a one-on-one meeting with an oil and gas representative, which yielded quality information about the process of oil and natural gas extraction.

The pilot-testing phase spanned a two-week period during December, 2011 and it was integral in the development of the final Q-set. Pilot testing several professors and graduate students that are well versed in the language of qualitative research proved helpful for a number of reasons, which were related to the choice of wording and the reduction of bias-creating phrases. The Q-set was finalized prior to construction of the Q-board, because both the number and nature of the statements dictate how the Q-board is to be constructed.

5.1.5 Construction of the Q-board

The Q-board (Figure 4.1 in Section 4.2.2) has three attributes that must be considered by the researcher: the point scale, the wording of the continuum range and the kurtosis of the distribution. The chosen point scale is dictated by the size of the Q-set and, according to the guidelines outlined in Section 4.2.2, a study like this one with less than 40 statements can safely employ a 9-point scale from -4 to +4. The wording of the continuum range refers to the description of the extreme ends of the point scale, which for reasons discussed in Section 4.2.2 combined with this study's interest in understanding importance, is "most important" to "most unimportant."

The third aspect of the Q-board is the distribution's kurtosis, an aspect that is a bit more subjective. The reasons for choosing either a normal distribution or a flatter distribution are explained in Section 4.2.2. The investigator for this study elected to employ a Q-board distribution that is approaching normal. The reason for the normal distribution is two-fold, and the main reason is related to the non-competing nature of several water-based ecosystem services being ranked. It was established that certain water-based ecosystem services being ranked by participants are competing (e.g. *commercial irrigation* and *in-stream flow*), but the majority of the ecosystem services being ranked can be received without impacting the availability of other services. For example, *household/municipal use* will not likely be impacted by *lake/reservoir recreation* and, for that reason, the Q-sorter is given ample space in the normally distributed Q-board for the ranking of services that may be both of little interest to them and are of little threat to the services that are important to them.

The second reason for the normal distribution of the Q-board is related to the nature of the inquiry, as opposed to the nature of the subject matter. It is well-known, and well-documented in Marc Reisner's (1993) book *Cadillac Desert: The American West and its Disappearing Water,* that the subject of water in the arid region of the Western United States is a contentious one with a long history. If this study were presenting opinions regarding potential uses of water, or the management of water then the distribution of the Q-board would be closer to flat, because it would be likely that most participants would have strong opinions on either topic. For example, if the Q-sorters were instructed to "rank the water-based ecosystem services from *most appropriate* to *most inappropriate* uses of water from your perspective," as opposed to, "rank the water-based ecosystem services from *most important* to *most unimportant* from your perspective," then a flatter distribution would be advisable. The investigator feels that the former set of instructions would place the Q-sorter in a more competition-based mindset, which would require more room on the extreme ends of the Q-board. The latter set of instructions is more likely to put the Q-sorter into a passive mindset, where they are deciding on what is important to them and, as a result, more room in the middle of the distribution, where ecosystem services of little relevance to the sorter can be placed, is appropriate.

5.2 Stakeholder Identification and Recruitment

Initial stages of development of the stakeholder list coincided with the start of the research project in May of 2011, and continued through the administration of the final survey on March 14th, 2012. The stakeholder list is presented in Table 5.2, and it was constructed with one goal in mind: inclusion of the widest range of water-related interests possible. The stakeholder list was built using a number of approaches: the researcher's personal knowledge of the study area, two meetings with local Forest Service employees, two focus groups with stakeholders, and snowball sampling employed during survey administration.

The foundation of the stakeholder list was developed using the study-area knowledge of the researcher combined with a thorough internet search. The driving question during this process was, "Who is interested in water?" When one considers the geographic, socio-economic, and political attributes of the study area, which were outlined in Chapter 3, there are a number of prominent groups or individuals that hold an obvious stake in water. Some of these groups and individuals include: farmers, ranchers, fishing and whitewater outfitters and guides, oil and gas industry workers, sovereign Indian Nations (Crow, Northern Arapaho, and Eastern Shoshone), natural resource managers at the local, state, and federal level, several non-governmental organizations, and the average citizen[13].

The list was expanded during two separate meetings with SNF land managers working for the Forest Service in Cody, WY. These meetings took place in October and November of 2011. Both meetings assisted the investigator by identifying more potential stakeholders to take part in the study, either as a focus group participant or as a Q-sorter. These meetings also provided the investigator with knowledge of specific places to administer surveys.

Prior to hosting the two focus groups, the researcher formatted a preliminary list of potential stakeholders into the following six categories using experimental design (see Section 4.2.3 for discussion on experimental design): private sector, non-governmental organizations, tribal governments, local government, state government, and federal government. Each category had a number of stakeholders that had been previously identified via literature review and Forest Service meetings. The list-in-progress was presented to the focus group participants with the question, "Who is missing?" These focus group meetings were effective in highlighting previously overlooked stakeholder groups.

[13] For lack of a better term, the average citizen is anyone who does not have an obvious stake in water, other than water for household and municipal use. For the purposes of this research, the average citizen is a resident of a town or city without an overt stake in water.

Table 5.2 Interests targeted for Q-sorting during data collection

Sector Interests/Groups	**Sector** Interests/Groups
Private Sector	**Tribal Governments**
Fishing outfitters and guides	Business council
Hunting outfitters and guides	Environmental Quality Commission
Whitewater raft companies	Fish and Game
Guest ranches	Engineers Office
Farmers	Water and Wastewater
Ranchers	Water Quality
Winter recreation enthusiasts	Employment Rights Office
Summer recreation enthusiasts	
Golf course/ski area employees	**Local Government**
Mining/Gas/Oil industry	County Commissioners
Average interested citizen	Town Mayors
Manufacturing/industrial use	Conservation Districts
Outdoor education	Weed and Pest Districts
	County Planners
Non-Governmental Organizations	Water and Sewer Districts
Wyoming Outdoor Council	Irrigation Districts
Wyoming Stock Growers Association	Wyoming Farm Service Agency
Wyoming Wilderness Association	
Greater Yellowstone Coalition	**Federal Government***
Trout Unlimited	Recreation
Wyoming Heritage	Climate Change Research
OHV Alliance	Hydrology
Wyoming State Snowmobile Association	Archeology
Biodiversity Conservation Alliance	Silviculture
Dude Ranchers Association	Planning
Federation of Fly Fishers	Hydropower
	Plant Ecology
Wyoming State Government	Soils Science
State Engineers Office	Natural Resource Extraction
University of Wyoming	Natural Resource Specialist
Cooperative Extension Services	Biology
Game and Fish Department	
Wyoming Water Development Commission	
Department of Environmental Quality	
Department of Agriculture	
State Parks	

**Note*: Workers from the following federal agencies were targeted to complete Q-sorts, but in order to protect confidentiality, the interests represented within the federal agencies will not be attributed to a specific agency: Bureau of Land Management, Forest Service, National Park Service, U.S. Fish and Wildlife Service, Bureau of Reclamation, Bureau of Indian Affairs, Natural Resources Conservation Services, and Army Corps of Engineers.

The final method used for the stakeholder-list expansion was the snowball technique, which is described in Section 4.2.3. In addition to assisting with the broad expansion of the stakeholder list, the snowball technique was especially helpful with regard to contacting specific stakeholders within a given interest group. For example, county commissioners were able to provide the investigator with the contact information for other county commissioners.

5.3 Administration of Surveys

The process of data collection took place from February 12, 2012 to March 14, 2012, and it included 96 interviews of a wide range of stakeholders and interested parties. Data collection took place mostly within the study area (see Figure 3.1), but there were some interviews done in Cheyenne, WY, Laramie, WY, Fort Collins, CO, and Bozeman, MT. This section will discuss the interview process.

Each interview started with the 14-question demographic survey (Appendix E), which is a task that generally took 5-10 minutes. Following the demographic survey was the Q-sorting exercise (see Appendix F for Q-sorting instructions given to each participant), which took about 40 minutes on average. Each participant was given a stack of 34 shuffled cards, each of which had the title of a water-based ecosystem service (see Section 6.1 for the complete list and definitions of water-based ecosystem services in the final Q-set) typed in bold on the top of the card, followed by the definition of each ecosystem service in unbolded font. In addition to the cards, the respondent was also given a Q-board, which was used in conjunction with the cards to express one's preference for various water-based ecosystem services. The participant was instructed to "please rank the statements on the cards from most important to most unimportant from your perspective. Each statement represents a water-based ecosystem service derived from the Shoshone National Forest." The researcher would follow-up this statement with a brief explanation of the term ecosystem service, and the process that was required to complete the survey. The researcher explanation noted that the term water-based ecosystem service was basically another term for benefits, and that when added together the benefits on the cards represented the full range of water-based ecosystem services being supplied by the SNF.

The respondent was then instructed to read through the cards and sort them into three separate piles: an important pile, an unimportant pile, and a final pile in the middle that represented those ecosystem services that one may not feel strongly about, positively or negatively (apathy evoking ecosystem services). From there, the participant was required to build the distribution represented by the Q-board. The researcher explained that the columns of the Q-board designated different levels of importance (+4,+3, etc.), but the rows did not. Therefore, a card placed in the far right column of the first row was of the same value as a card placed in the far right column of the second row. Likewise, a card placed in the bottom of the middle column (designated by the 0 value) and a card placed at the top of the middle column were of equal value. The researcher finished the instruction by noting that the respondent was required to "choose your two most important benefits, followed by your next three, until you reach the middle column. Then go to the left and pick your two most unimportant benefits and work your way back to the middle. In the end you should have a pyramid similar to the Q-board, at which point we will record the numbers from the back of the cards onto the Q-board."

Following the Q-sort was a short discussion (about 10 minutes) regarding the two water-based ecosystem services that the respondent chose as most important. For example, if the respondent chose hydropower and commercial irrigation as the two most important ecosystem services, then they would be asked the following question for each service: "What factors, influences, or things do you see as potentially affecting your ability to receive hydropower in the future, either positively or negatively?" This same question would be posed with regard to commercial irrigation following the answer given about hydropower.

After these two questions were answered by the participant, the researcher asked the four questions below, which were intended to discover if the participant perceived a changing climate as a threat to their two most important benefits. Due to the controversial nature of the subject of climate change, advice from colleagues, and the anticipated viewpoints of many potential participants, the researcher initially chose to take an indirect approach to discuss climate change. Therefore, the four questions presented to the participant did not explicitly mention climate change.

Follow-Up Discussion Questions[14]

1.) Research has found that the peak river runoff is happening progressively earlier. For example, one study indicated that the center-of-volume date was about 4 days earlier in the 1990s vs. the 1950s in the Clarks Fork of the Yellowstone River

[14] The full citation for the references contained in each question was provided to the participant, but the reader here is referred to the reference section for the full citation.

(USGS, 2005). Do you think an earlier runoff would affect your ability to receive your most important service in the future?

2.) Research has found that there are progressively more frost free days, which implies a warmer late spring and early fall. One study suggested that from 1948-1999 the study area saw nearly 9 more frost-free days (Easterling, 2002). Do you think this would affect your ability to receive your most important service in the future?

3.) Research has found that glaciers are rapidly melting. One study showed a 25% decrease in Wind River Range glacial area between 1985 and 2005 (Cheesbrough et al., 2009). Does the rapid melting of glaciers impact your ability to receive your most important service in the future?

4.) Research has found that the average annual minimum temperature is increasing. One study showed an increase of 2.6 ºF per decade (1986-2009) of annual average minimum temperature for the combined SNOTEL sites (Rice et al., 2012, p. 10). Do you think an increase in average minimum temperatures would affect your ability to receive your most important service in the future?

The indirect approach to the climate change discussion was quickly modified in the field, however, when the respondents early on realized that the questions, as Participant 3 stated, were "geared toward climate change." This reaction to the questions fostered an ethical consideration for the researcher, which was one of potentially feeling as though the researcher had deceived the respondent into answering the questions without divulging the true intent. To avoid this possibility, from the fourth interview onward the researcher presented the questions with a lead-in statement explaining that the project was interested in understanding if people viewed a changing climate as a threat to their two most important services. It was also noted, however, that the research was not interested in discussing the cause of a changing climate in order to avoid the potentially incendiary question of, "is climate change human-made or not?" Each of the four questions were asked with regard to both of the two most important services.

5.4 Data Analysis

The investigator chose the computer program PQMethod for analysis of the Q-sorts, and the reasons for this decision are outlined in Section 4.2.5.3. PQMethod is a basic program that runs in DOS, which takes some getting used to because navigation of the program requires text commands without the use of a mouse. However, the simplicity of the program is quite nice once the investigator has a basic handle on the required commands. The first screen that appears in PQMethod is the main menu, which has the following nine operations to choose from:

1- STATES – Enter (or edit) the file of statements

2- QENTER – Enter q sorts (new or continued)

3- QCENT – Perform a Centroid factor analysis

4- QPCA – Perform a Principal Components factor analysis

5- QROTATE – Perform a manual rotation of the factors

6- QVARIMAX – Perform a varimax rotation of the factors

7- QANALYZE – Perform the final Q analysis of the rotated factors

8- View project files

X- Exit from PQMethod

This section will describe the process of using PQMethod to analyze the 96 Q-sorts collected from the stakeholders on water-based ecosystem services derived from the SNF.

5.4.1 Data entry

The first step in PQMethod is true to its description, and it consists of entering each statement from the Q-set into the program. There is a character limit for each statement, which requires the investigator to enter some part of the statement that makes it identifiable during later steps. In the case of this study, the 34 statements could not be entered in their entirety, but the titles (bolded portion in Q-set presented in Section 6.1) for each water-based ecosystem service were below the character limit and, as a result, they were chosen for entry into "the file of statements" for step 1.

Step 2 required the entry of each of the 96 Q-sorts in the program, a process that was made simple by the program. PQMethod has a built-in checking apparatus, which does not allow an investigator to incorrectly enter a Q-sort. For example, if an entered Q-sort is missing a statement, has a duplicate statement, or has too many (or too few) statements in a column then the program will notify the operator of the issue, and immediately offer a simple fix to the problem.

5.4.2 Factor analysis or PCA?

Once the statements and the Q-sorts are entered into PQMethod, the researcher has to decide between employing the centroid method or PCA for analysis of the covariance matrix. As explained in Section 4.2.5.3, both methods produce similar results and, in order to be thorough, the researcher employed both the centroid method and PCA during the preliminary stages of analysis. The comparison of findings from use of the centroid method and PCA will be presented in Chapter 6. In the end, the centroid approach was adopted for reasons outlined in Section 4.2.5.3. Also, the preliminary results supported the decision to use the centroid method.

5.4.3 Extraction of unrotated factors

Factor analysis using PQMethod requires that the investigator make two main decisions following the choice of PCA or the centroid method: how many factors to extract initially, and how many of those initially extracted factors should be kept and rotated. The first decision results in the unrotated factor matrix, and the second results in the rotated factor matrix. Ultimately, the rotated factor matrix is used to construct the factor arrays, which are the objects of interpretation.

The decision on how many initial factors to extract can be influenced by the objective criteria presented in Section 4.2.5.3, the theoretical inclinations of the researcher, or both. There is not a single correct way to decide on the number of initial factors to extract, and it may be best to extract more initial factors than thought to be necessary. The Q-methodology literature is rather ambiguous when it comes to differentiating between the use of objective criteria for deciding the number of initial factor to extract, or the number of factors to rotate and interpret. In fact, the unrotated factor loadings derived from centroid factor analysis are unchanged by extracting more or less initial factors. In other words, the factor loading for any Q-sort on factor 1 of the unrotated factor matrix will be the same if one factor is initially extracted, or two factors is initially extracted, or three, or four, and so on.

There are few reasons to extract less than seven factors, and there are also several reasons to extract more initial factors than thought necessary. First, PQMethod sets an upper boundary by allowing a maximum of eight factors to be initially extracted, but the program default is set at the extraction of seven initial factors. The "magic number of seven" rule discussed in Section 4.2.3.5 recommends that seven factors is a good place to start. Additionally, a study with a large number of Q-sorts (96 in this study) clearly indicates that extracting the maximum number of seven factors is a sound approach if using the rule of "one factor for every 6-8 participants" outlined in Section 4.2.3.5. Preliminary research revealed that the initial extraction of seven factors resulted in each factor having an eigenvalue greater than one, which is an indication that they all should be extracted. Finally, the exploratory nature of the researcher's goal of understanding the full range of perspectives regarding the importance of water benefits coming from the SNF advocates the consideration of as many viewpoints as possible, regardless of their prominence. Therefore, the researcher chose to extract seven factors initially.

5.4.4 Rotation of factors and flagging

The operation that has the largest implication for the final solution, and the subsequent interpretation, is the number of factors chosen for rotation. The use of the objective criteria presented in Section 4.2.5.3 can help to guide the researcher in deciding how many factors to extract for rotation. During the rotation process in PQMethod, the investigator is also required to decide if the Q-sorts should be automatically flagged or manually flagged. The flagging process was discussed in Section 4.2.5.6 and, for this project, the investigator elected to manually flag all *pure* Q-sorts that were significant at the p-level of 0.01. Manually flagging Q-sorts at a p-level of 0.01 is a more rigorous approach than that used by the automatic flagging option in PQMethod (which uses a p-level of 0.05), which results in factors that are more unique, because only pure Q-sorts with a loading of greater than, or equal, to 0.44 (equation used to arrive at this value is discussed in Section 4.2.5.3) are used to construct the factor array. The use of a more liberal-flagging criterion can potentially increase the correlation between factor scores, which is an output of PQMethod that was discussed in Section 4.2.5.6. Within the context of this project, the investigator compared auto-flagging approach to manual-flagging approach and found that, overall, the manual-flagging approach led to lower correlations between factor arrays, which is desirable in Q-methodology because it is indicative of the more distinct viewpoints.

5.4.4.1 Choosing a rotated-factor solution

As explained in Section 4.2.5.4, there is no definitive rule for deciding which rotated solution is best, but the literature suggested to try several rotations and pick the solution that described the data *most appropriately*. Deciding which solution describes the data *most appropriately* is an area in Q-methodology that could potentially introduce researcher bias because, as mentioned in Section 4.2.5.4, there are both statistical and theoretical considerations. The objective criteria outlined in Section 4.2.3.5 are guidelines for choosing the best-rotated solution, which should be applied in conjunction with theoretical considerations and the overarching goals of the research. For this project, the investigator applied four objective criteria: (1) the eigenvalue test; (2) Scree test; (3) Humphrey's rule; and (4) the significant loadings test.

Use of objective criteria can only help to *guide* the researcher to the *most appropriate* rotated solution. The use of objective criteria does not necessarily indicate with certainty which rotated factor solution is best. Therefore, as explained in Section 4.2.5.3, there are other theoretical and statistical considerations when deciding on the most appropriate rotated-factor solution. Theoretical considerations can sometimes take precedent over statistical considerations, as was the case when Brown (1980, p. 40) included a factor that was defined by "the ultimate decision maker," despite it being statistically unfit. For this project on water-based ecosystem services, though, there was no single *ultimate decision maker* participant. The chief of the Forest Service may have fit this description, but he was not interviewed for this project.

Even though there were not any theoretical considerations used by the investigator to decide the most appropriate rotated factor solution, there were other statistical considerations, which include factor reliability (see Appendix B.9); explained variance; the existence of bipolar factors; and the distribution of pure Q-sorts, confounding Q-sorts, and null Q-sorts.

5.4.5 Interpretation and articulation of the chosen rotated-factor solution

Following the decision of which rotated-factor solution was *most appropriate,* the investigator must interpret and articulate the meaning of the resulting factors. The methods for interpretation and articulation of results are explained in Section 4.2.5.6. For this project, each factor will be explained separately, and each explanation will include a factor array with statistically distinguishable statements highlighted, crib sheet, and interpretive write-up. The output of PQMethod for the chosen factor solution was used to develop each factor array (see Appendix G for the z-scores used to develop each factor array).

The factor arrays, as explained in Section 4.2.5.6, are the objects of interpretation and, to facilitate that interpretation, the investigator color-coded the water-based ecosystem services with production ecosystem services in red, regulating ecosystem services in blue, and cultural ecosystem services in green. The different types of ecosystem services are discussed in Section 2.1.1, and the classification approach used for this project most closely resembles the approach used by Hein et al. (2006).

Even though a holistic interpretation of the resulting factor arrays is recommended, Q-methodologists stress the need to pay special attention to those statements for each factor that are statistically distinguishable. Therefore, the statistically distinguishable statements will be those highlighted in black within each factor array. The use of crib sheets, as described in Section 4.2.5.6, is meant to ensure that the investigator interprets each factor array holistically, and does not only concentrate on those statements that occupy the extreme ends of the Q-board. Also, the crib sheet can help to identify those statements of a factor array that may be in need of attention, but are not statistically distinguishable.

The interpretive write-up, as explained in Section 4.2.5.6, can be completed using the narrative approach or the commentary approach. For this project, the narrative approach was adopted because it does not require the investigator to present each relevant statement, "cited in full," within the interpretive write-up, which is an attribute of the commentary approach (Watts & Stenner, 2012, p. 162). Using the narrative approach will result in interpretive write-ups that are more concise, and the nature of the statement titles for this project will ensure that the reader is adequately informed of the factor's viewpoint. The interpretive write-ups start with a factor name and basic information about each factor, which includes the variance explained, number of defining Q-sorts, and demographic information about those participants that loaded onto each factor.

The interpretive write-ups, when possible, will include qualitative data from participants that loaded significantly onto the factor being explained (see Appendix H for the full transcriptions of every follow-up discussion). According to Watts and Stenner (2012), the use of qualitative data can enhance factor interpretation. The use of qualitative data can also serve as a safeguard to researcher bias by limiting the opportunities for the researcher to make their own connections. In other words, it is beneficial to use the exact wording of a participant when surmising why certain viewpoints exist. For example, if a factor array illustrates that *water quality* is important (+4 on the Q-board) and *oil and natural gas extraction, and mining* is unimportant (-4 on the Q-board); it may be a reflection of participants recognizing that one ecosystem service threatens the other, however, the researcher would be drawing their own conclusions if the interpretation was devoid of direct qualitative data from the participants. The interpretive write-ups will also use information specific to the study area to support the reasoning being used to describe each factor.

5.5 Drivers Discussion

Following the interpretation and articulation of the factors, will be a discussion of the drivers or impacting factors that stakeholders felt would affect the flow of their most important water-based ecosystem services. The follow-up questions presented in Section 5.3 were asked to the participants in order to facilitate a discussion, hereafter known as the 'drivers discussion', which supplied the investigator with qualitative data for two purposes: (1) to supplement the interpretation of the factor arrays, which is an important aspect of Q-methodology because, as Stergiou and Airey (2011, p. 316) asserted, the Q-sorts that eventually help to define the factor arrays are, on their own, representative of "the 'skeleton' of subjectivity, which only becomes interpretable through the comments and reflections of the participants"; and (2) to gain understanding of stakeholders' perspectives related to the threat of climate change, and other drivers, to the flow of important water-based ecosystem services.

Some information gathered during the drivers discussion has been presented within the interpretive write-ups of the factors. However, the majority of the information gathered during the drivers discussion has been used to highlight the elements, with a focus on climate change, that stakeholders thought would impact their most important ecosystem services. The information gathered from the drivers discussion is presented in two sections. The first section discusses stakeholders' perspectives regarding the threat of climate change to those ecosystem services that were 'most important' (+4 on the Q-board), and the second section presents other drivers that stakeholders felt would impact the flow of their two 'most important' water-based ecosystem services.

5.6 Summary

This chapter highlighted how Q-methodology was employed in the context of this project, which aimed to elicit preferences for a wide range of water-based ecosystem services derived from the SNF. The first step included the creation of the concourse, Q-set and Q-board, which was followed by the creation of the P-set. The stakeholders that comprised the P-set where then required to complete a Q-sort, which were the objects of analysis and interpretation. Finally, the drivers discussion was used to both supplement the interpretation of the factors that resulted from analysis of the Q-sorts, and to identify the factors or influences that stakeholders felt would impact the flow of their two 'most important' ecosystem services.

Chapter 6

Results of a Q-Methodology Study on Water-Based Ecosystem Services Derived from the Shoshone National Forest

The results of this Q-methodology study are featured in this chapter, and will include a discussion of the composition of the concourse and Q-set, the composition of the P-set, the results of data analysis and the interpretation of those results. This chapter provides the reader with evidence that the objectives outlined in Chapter 1.2 have been addressed. The final Q-set is representative of the full range of water-based ecosystem services being derived from the Shoshone National Forest (SNF), which was the goal of objective 1. The P-set is composed of stakeholders that benefit from the various ecosystem services that make up the Q-set, and it represents the completion of objective 2. The results of data analysis will provide the reader with an understanding of what water-based ecosystem services are important to various stakeholders, which is the goal of objective 3. Following the interpretation of the results will be a discussion of which factors, according to the stakeholders, may influence or threaten the stakeholders' ability to receive their most important water-based ecosystem services, which is a discussion that addresses objective 4. These findings are presented in Sections 6.1, 6.2, 6.3, and 6.4, respectively.

6.1 Concourse and Q-set

The methods used to develop the concourse are discussed in Section 5.1. Initially, a thorough review of both literature related to ecosystem services and literature related to the study area was completed, which resulted in a preliminary list of 23 water-based ecosystem services, henceforth referred to as the concourse (see Appendix C). The use of focus groups and pilot tests were integral in the shaping of the concourse into the final list of 34 water-based ecosystem services defined in Table 6.1, and referred to hereafter as the Q-set. The italicized rows in Table 6.1 classify the ecosystem services by function.

The following three subsections explain how the focus groups, pilot tests, and other informal discussions shaped the concourse into the Q-set, and discuss the classification of water-based ecosystem services in the Q-set into categories by function.

Table 6.1 Q-set with water-based ecosystem services classified by function

Ecosystem service title	Ecosystem service definition
Regulating services makeup 9 out of 34 statements in the Q-set	*"Regulation services result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes" (Hein et al., 2006, p. 212).*
Water quality	The water in and flowing from the SNF is purified and filtered by natural systems like beaver ponds and wetlands resulting in clean water.
Conservation of rare plant species	Wetlands within the study area support a number of rare plant species. The rare plants may have some use that is unknown to humans at this time, but they could be beneficial in the future.
Conservation of keystone (critical) species	The water within the study area helps to support important plant and wildlife species. For example, the whitebark pine, beaver, and cutthroat trout are considered keystone species of the Greater Yellowstone Ecosystem (GYE), which means they are important for the conservation of a host of other species.
Nutrient cycling and sediment transport	The water flowing from the SNF helps to cycle nutrients and transport sediment. Nutrients cycled throughout the natural system helps to maintain healthy and diverse aquatic habitats. The transport of sediment helps to create floodplains and riparian areas.
Natural flood control	The storage of SNF water in glaciers, wetlands, riparian areas, and aquifers provides natural flood control, which avoids flooding damage costs.
Biodiversity conservation	Aquatic and riparian areas fed by the SNF provide habitat for a diversity of species, and genetic variation within species. Species diversity may help maintain ecosystem structure, processes and functions.
In-stream flow	The water from the SNF that is not drawn from the river can help to create and maintain healthy aquatic habitats. For example, a certain amount of water in the stream can maintain channel form and function, and regulate water temperature.
Glacier-based services	The glaciers in the SNF are of the largest concentration in the lower 48 states, and they provide unique services like stream-water temperature regulation, summertime skiing, and glacier sightseeing.
Gradual discharge of stored water	Water released into streams and rivers is naturally regulated by glaciers, wetlands, riparian areas, and aquifers, which provides a reliable flow of water throughout the year, even during the warmest summer months.
Cultural Services makeup 16 out of 34 statements in the Q-set	*"Cultural services relate to the benefits people obtain from ecosystem through recreation, cognitive development, relaxation, and spiritual reflection" (Hein et al., 2006, p. 212).*
Non-motorized ice and snow based recreation	The ice and snow within the study area can be used for a number of non-motorized winter recreational activities. Some include: skiing, snowboarding, ice climbing, winter camping, and snowshoeing.
Motorized ice and snow based recreation	The ice and snow within the study area can be used for motorized winter recreational activities like snowmobiling.
River recreation	The rivers flowing in and out of the SNF can be used for both whitewater and scenic recreational activities. Some include: rafting, kayaking/canoeing, stand-up paddle boarding, tubing, body boarding, surfing, river-access hiking, and bird watching.

Commercial water-based recreation	Outfitted whitewater rafting trips and guided-fishing trips are two examples of commercial water-based recreation sold on the market. Both opportunities are provided by the water resources in the study area.
Lake/Reservoir recreation	The lakes and reservoirs in the study area provide opportunities for recreational activities. Some include: water skiing, wakeboarding, kneeboarding, skurfing, tubing, sailing, motorboating, parasailing, canoeing, kayaking, and kiteboarding.
Recreation/Leisure activities done near water	For example, the experience of wildlife viewing and hiking could be done in close proximity to a water resource within the study area. Additionally, reflective recreational activities like introspective thought may be done near water.
Lake/Reservoir fishing	The lakes and reservoirs in the study area provide the opportunity for fishing, both for sport and the harvesting of fish for personal consumption.
River-based fishing	The rivers throughout the study area can be used for fishing, both for sport and the harvesting of fish for personal consumption.
Lake, reservoir, and river-based hunting	The lakes, reservoirs, and rivers throughout the study area provide opportunities for hunting waterfowl from the water in a boat.
Land-based hunting	The water resources in the study area provide habitat for game and, as a result, watercourses and wetlands can be used for land-based hunting.
Physically and mentally challenging recreation	The water environments within the study area can provide opportunities for physically and mentally challenging recreational opportunities.
Preserving livelihoods, lifestyles, and landscapes	The water flowing from the SNF is used to support healthy agricultural communities and large working farms and ranches.
Native American cultural and spiritual values	The water resources in the study area have special meaning to Native Americans, and can be used for cultural, spiritual, religious and ceremonial purposes.
Non-Native American cultural and spiritual values	The water resources in the study area have special meaning to Non-Native Americans, and can be used for cultural, spiritual, religious and ceremonial purposes.
Inspirational and aesthetic values	The rivers and lakes in an around the SNF can provide inspiration and enjoyment. For example, a scenic water vista can provide the motivation for an artist's work, and the beauty, smell, and sound of water can provide enjoyment.
Education, management and science	The aquatic habitats and water-based ecosystem processes within the study area can be studied with the goal of improving both management and objective knowledge of natural and social sciences, which include biology, botany, hydrology, and history.
Production Services makeup 9 out of 34 statements in the Q-set	*"Production services reflect goods and services produced in the ecosystem" (Hein et al., 2006, p. 212).*
Household/Municipal water	Water in the study area, both surface water and groundwater, can be used for drinking, washing, and other in-house use.
Commercial irrigation	The water in the study area, both surface water and groundwater, can be used to irrigate commercial crops, which could include hay, sugar beets, corn, grain, barley, and beans. These crops could be sold on the market and/or used to support ranching activities.
Personal irrigation	The water in the study area, both surface water and groundwater, can be used to fill private ponds, and irrigate gardens and lawns.
Water for stock	Water provided by the SNF can be used for the watering of stock.

Fighting forest fires	Water provided by the SNF can be used for the fighting of forest fires.
Manufacturing and industrial	The water in the study area, both surface water and groundwater, can be used for manufacturing and industrial purposes.
Oil and natural gas extraction, and mining	The water in the study area, both surface water and groundwater, can be used for the extraction of natural gas and oil, and to a lesser extent, in the mining of coal, bentonite, uranium and gypsum. Water is also used in these industries for dust control on roads.
Hydropower	Water provided by the SNF can be used to generate hydropower.
Supporting of commercial land-based recreation	Water provided by the SNF facilitates land-based recreational activities. For example, the watering of golf courses, the water used to make snow for the Sleeping Giant Ski Area, and the water used for amusement parks.

6.1.1 Focus group expansion of the concourse into the Q-set

The methods used for conducting the focus groups for the development of the Q-set are discussed in Section 5.1.3. The primary goal of the focus groups was to identify and define as many water-based ecosystem services derived from the SNF as possible.

The process of defining the water-based ecosystem services was not as smooth as the researcher had envisioned; however, the discussions that ensued were invaluable for informing the decisions regarding how to articulate the ecosystem services and whether or not to merge or separate certain ecosystem services. For example, following the group consensus that *commercial irrigation* should be an ecosystem service, it quickly became clear to the investigator that a concise definition for *commercial irrigation* as presented in the Q-set would not be attained. However, the discussion regarding irrigation in general confirmed that it was necessary to separate irrigation into *commercial* and *personal.* Furthermore, the focus group discussions were also beneficial in ensuring that the important aspects of each ecosystem service were presented in the final definitions. For instance, the original definition for *personal irrigation* did not include the aspect related to filling ponds, but the focus group discussions highlighted the importance of the water received from the SNF for this purpose.

The expansion of the concourse into the Q-set was mainly facilitated by the focus group discussions. Combined with the four criteria outlined in Section 5.1.1, the challenge of deciding how specific each water-based ecosystem should be was overcame by the input of focus group participants. For example, the investigator was unsure how specific to be with the ecosystem services related to fishing and hunting. The concourse included two ecosystem services related to fishing and hunting, which were entitled *river-based fishing and hunting recreation* and *lake/reservoir fishing and hunting recreation*. The Q-set included four ecosystem services related to fishing and hunting, which were entitled: *land-based hunting*; *lake, reservoir, and river-based hunting*; *river-based fishing*; and *lake/reservoir fishing.* The decision to have separate ecosystem services for hunting and fishing was influenced by the following comment from Focus Group Participant 8 (all focus group participants are numbered to protect their confidentiality):

> I think I see hunting and fishing as separate only because I think one is indirect and one is direct. I think people can, sort of, mentally connect the importance of water for fisheries and fish. But it's a step back for them to understand the importance of water for the wildlife that they are hunting.

This quote, combined with the fact that not all people that fish are also hunters (and vice versa), is evidence that presenting an ecosystem service that included both hunting and fishing might create some conflict for the Q-sorter, which could result in a more difficult sorting exercise and an inaccurate ranking by the Q-sorter.

Another change, with regard to hunting and fishing, between the concourse and Q-set was the inclusion of *land-based hunting* as a water-based ecosystem service, which may seem oxymoronic. However, the focus group discussions firmly established that hunters spend a great deal of time near water because that is where big game gathers. Focus Group Participant 4 noted:

> [People] camp by the water to hunt big game.

For fishing, the Q-set had a separate ecosystem service for *river-based fishing* and *lake/reservoir fishing*, the reason for which can partly be attributed to all people not doing both types of fishing (some people lake fish and some people river fish, but not everybody does both). Additionally, the focus group discussions indicated that there are two types of fishing ethic: a river-fishing ethic and a lake-fishing ethic. Focus Group Participant 1, who is familiar with the fishing culture in the study area explained:

> With fisherman it is not as much of a blood sport as it used to be. I think we are seeing a lot more people becoming interested in preserving native species like the Yellowstone Cutthroat or Westslope Cutthroat, or Golden Trout or whatever. They want to see them in their native habitat in order to have them there for their children or their grandchildren. The idea of using a barbless hook or a single hook, versus a treble hook and handling those fish in a way that they have a good chance of survival…you are seeing more of that. You are seeing less of the harvest stuff. Now you see that on reservoirs because the perception is those fish are there to be

> caught and consumed. But in some of the wilder rivers like we have in this part of the State, and in the Forest, I think you are seeing a lot more of the ethos go that way, to the non-blooded part of the experience for fishing.

It is clear that this Participant sees the two types of fishing as different, with river fishing having an ethic that is different from reservoir fishing. The former concentrates on the sporting aspect, and the latter focuses on the consumption aspect. This is a convenient time to remind the reader that Q-methodology is focused on understanding the full range of perspectives regarding some topic, which means that all perspectives are important, no matter how prevalent. Therefore, the inclusion of both an ecosystem service for fishing on lakes and reservoirs and for fishing on rivers is appropriate if it potentially facilitates the expression of a unique perspective.

The sporting/consumption aspect of both types of fishing highlights another modification made by the investigator, which was the dropping of the word *recreation* in the title of the ecosystem services related to hunting and fishing. The use of the word *recreation* in relation to fishing was explicitly applying a reason for doing that activity. In other words, there was a chance that the Q-sorter would be conflicted when sorting an ecosystem service labeled *river-based fishing recreation* if they were the type of person that fished for the food only. Therefore, the final Q-set definitions for fishing related services stated that the fishing opportunities were *both for sport and the harvesting of fish for personal consumption.*

Unlike fishing, the Q-set combined hunting opportunities on lakes, reservoirs, and rivers into one ecosystem service entitled *lake, reservoir, and river-based hunting.* It became evident during the focus groups that there was a small population of hunters that directly used the rivers, lakes, and reservoirs in the study area for hunting, but there was no evidence of a separate group of hunters that only used the rivers, or a group of hunters that only used lakes and reservoirs. However, there was clearly a different, and larger, population that hunted on land, but in close proximity to waterways.

A similar rationale used for the inclusion of *land-based hunting* in the Q-set, led the researcher to include *recreation/leisure activities done near water* in the Q-set, which was an ecosystem service that was not considered prior to the focus groups. This is another ecosystem service that involves the interaction with blue water. Focus Group Participant 16 explained:

> To me, hiking, backpacking, camping, hunting- I mean you are not in the river all the time, but it is all dependent on the water. I mean, that is one of the things that I like about recreating here is you got water all over the place. You really do not have to carry your water. Maybe it is just secondarily related, but water is still a factor.

Also, Focus Group Participant 15 stated:

> When you talk about hiking and these land-based activities. Most of them are done in the canyons and stream corridors. On the reservation at any rate, people are hiking back to lakes to fish. So the hiking is water-based.

There was a lake, reservoir, and river consideration with regard to recreational activities that were not related to hunting and fishing (e.g. kayaking, rafting, sailing). The concourse included *whitewater river recreation,* and *scenic river recreation,* but the Q-set condensed these ecosystem services into one with the title *river recreation*, which included both whitewater and scenic river recreational activities. The reason for this decision was based on the management criterion discussed in Section 5.1.1.3. The investigator operated on the assumption that river recreation, that was not hunting or fishing based, would be managed in a similar manner. Also, a day on a river that contains whitewater will also likely include some scenic activities, which was another reason that the two activities were included in the same water-based ecosystem service. It became evident that the separation of *lake/reservoir recreation* and *river-based recreation* into two different ecosystem services was appropriate when Focus Group Participant 1 stated that river recreationists and lake/reservoir recreationists are "different breeds of cat." Also, both the management criterion and conflict criterion influenced the decision to separate the two types of recreation.

The focus groups were effective in highlighting several ecosystem services that were not included in the concourse, for example, the need for an ecosystem service that stressed the overall benefit of agricultural communities in the study area. The study area, and the whole state of Wyoming, was built on agriculture dating back to the Homesteaders. As a result, the agricultural community is considered to be important by more than farmers and ranchers. The ecosystem service *preserving livelihoods, lifestyles, and landscapes* was developed because, as Focus Group Participant 2 noted, agriculture is "a layer of protection" against development. Focus Group Participant 8 explained:

> The absolute importance of agriculture. I mean the importance of water to agriculture, whether it be farming or ranching, but the importance of agriculture to the economy but, also, to some of the most important aspects of this region. Park County ranks 15th in the Rocky Mountain West to the threat of subdivision of private ranch lands. These ranches are holding this ground, holding habitat for species, stewarding these lands in large unbroken blocks. Their economic viability is tied to water. If they become unviable for whatever reason, then they are at greater risk to subdivision and then we lose a lot of important characters that we appreciate including: viewshed, habitat for wildlife, biodiversity…But it is also, I mean it really would change the character of this landscape for the people that appreciate it, and I think we would see a significant change in wildlife population. It would also impact our culture and heritage. I think we can't undervalue the importance, I wouldn't look at irrigation as a draw per se on the water, but it really plays such an important role in sustaining agriculture. It plays such an important role in this community.

Another ecosystem service that was not included in the concourse, but was identified by the focus groups was *commercial water-based recreation.* The focus groups stressed that it was important to have an ecosystem service dedicated to commercial recreation because it drives the economy and, as Focus Group Participant 1 noted, it is a "money making endeavor." Additionally, use of the management criterion made apparent the need to include an ecosystem service dedicated specifically to commercial recreational pursuits, because the handling of commercial outfits is wholly different from the handling of private recreationists (e.g. permit requirements) by land management agencies.

The inclusion of regulating services such as *biodiversity conservation, conservation of rare plant species,* and *conservation of keystone (critical) species* in the Q-set was due to the focus group discussions, and consideration of the management criterion. The investigator is aware that the three aforementioned ecosystem services may contain overlap (e.g. water that provides support of overall biodiversity conservation also supports the conservation of rare plant species and keystone species). However, the benefit of including each ecosystem service was potentially large when considering the management criterion and that Q-method's goal is the presentation of the full range of perspectives, in a nuanced fashion, regarding some topic of interest. The following two comments by focus group participants illuminated the special status of keystone species and rare plants:

Focus Group Participant 8:

> Biodiversity covers the breadth of the species, but specifically the keystone species are integral to the system itself. Biodiversity looks at, we do not want loss of species from the system, but then there are keystone species.

Focus Group Participant 6:

> Rare plants as well, I mean, you can think biodiversity, but there are a number of rare plant species that are supported by water.

Another regulating service that can be credited to the focus groups is *nutrient cycling and sediment transport.* As Focus Group Participant 12 concisely stated:

> [Nutrient cycling and sediment transport] brings the eroded mountains out to the plains. It creates floodplains, and riparian areas. This whole basin is sediment that has been deposited by the river.

The definition used for this ecosystem service in the Q-set is a good example of employing the direct phrasing of the participants, which is an ideal quality of any Q-set (a point that is discussed in Section 4.2.1).

The regulating ecosystem service entitled *water quality* was added to the Q-set, because of the focus group discussion regarding water filtration. Including water filtration as an ecosystem service was pondered, but it was decided that water filtration was more of an ecosystem function that provided the service of clean water. Initially, the investigator considered the ecosystem service entitled *in-stream flow* as a supporting service that provided both water quality and quantity. However, as the focus group conversations developed it became clear that it was necessary to have an ecosystem service for *water quality* and an ecosystem service for *in-stream flow.* The definitions for both ecosystem services were formed from exact phrasing of the participants. With regard to *water quality*, Focus Group Participant 6 stated:

> We've got our wetlands up there, we've got our fens, we've got all of these processes that are naturally purifying the water….we have one of the purest water sources around.

Focus Group Participant 19 noted the following about water filtration:

> Beavers will build dams. The water is coming off the top pretty fast and bringing a lot of dirt with it, hits a beaver pond and settles out, goes over and picks up speed again and hits the next beaver pond. By the time you get to a rock-based creek you have clean water. So the wildlife help us with the sediment coming down.

The definition for *in-stream flow* was, in part, informed by the following comment made by Focus Group Participant 6:

> Channel forming factors, if we do not have a certain amount of water in the stream, how are we going to maintain channel form and function?

The final regulating ecosystem service added to the Q-set as a result of the focus groups was *gradual discharge of stored water,* which was derived from the focus group discussion on water storage. A number of participants stressed the importance of water stored in glaciers, aquifers, lakes and reservoirs. Focus Group Participant 16 stressed the importance of both "natural and man-made water storage," however, the exclusion of the human-made storage is the result of the naturalness criterion.

The focus groups proved to be fruitful for the task of developing a comprehensive Q-set on the full range of water-based ecosystem services derived from the SNF. However, pilot testing and other less-structured discussions were employed to finalize the Q-set.

6.1.2 Results of using pilot tests and informal discussions to finalize the Q-set

The methods used for both pilot testing and the gathering of input from those interests that were not included in the focus groups was discussed in Section 5.1.4. This section will discuss the results of the single pilot test done with a stakeholder in the study area, as well as the discussions had with stakeholders that were not able to attend the focus groups. Also, this section will discuss the pilot tests done with graduate students and faculty at The University of Montana, which were helpful for finalizing Q-set statements in a way that minimized potential researcher bias.

The informal discussion with an employee in the oil and natural gas industry was helpful to ensure that an accurate definition for the *oil and natural gas extraction, and mining* ecosystem service was included in the Q-set. The pilot test and discussions with Tribal members in the study area were informative. The main lesson learned from these interactions was the need to have a separate ecosystem service for *Native American cultural and spiritual values* and *non-Native American cultural and spiritual values*, because even though both groups derive cultural and spiritual values from the water resources in the study area, it became evident that there is a difference between the two types of values.

Pilot testing with graduate students and faculty from The University of Montana was helpful to create a final Q-set that was devoid of potentially biasing phrases. For example, the concourse and early versions of the Q-set included statements that not only defined the water-based ecosystem service, but also articulated a potential benefit for that ecosystem service. For instance, the definition of *physical and mental challenge* was, initially: *the environment within the study area can provide opportunities for physical and mental challenge, both of which can have various health benefits.* The final definition of *physically and mentally challenging recreation* was: *the water environments within the study are can provide opportunities for physically and mentally challenging recreational opportunities.* The final definition did not include the part about the health benefits, because it may have been a phrase that inflated the importance of the ecosystem service in the mind of the Q-sorter.

Another example of the elimination of potentially biasing phrases is related to glaciers and other unique features in the study area. The final Q-set included a single ecosystem service related to glaciers, which was entitled *glacier-based services* and was defined as, *the glaciers in the SNF are of the largest concentration in the lower 48 states, and they provide unique services like stream-water temperature regulation, summertime skiing, and glacier sightseeing.* However, the concourse has two separate ecosystem services devoted to glaciers: *glacier tourism services*, and *glacier melt water*; and one reserved for *unique recreational activities*, which mentioned a unique glacier within the SNF. The two glacier-related ecosystem services were merged into one because the *glacier melt water* was included in the ecosystem service for the *gradual discharge of stored water.*

The elimination of the ecosystem service for *unique recreational activities* from the concourse was due to it being potentially biasing, which was implied when a pilot tester noted that just because the investigator feels that a recreational activity is unique and worth mentioning does not warrant its inclusion in the Q-set.

The addition of the term *management and science* to the ecosystem service titled *education, management and science* was the result of a pilot tester being confused about the definition. In this case, the pilot tester felt that ecosystems were important for the application of trial management techniques, but the original title of *education* created ambiguity about the meaning of the ecosystem service. Another minor change that resulted from the pilot tests was the dropping of capital letters for every word in the title of each ecosystem service, because it was considered a source of confusion with the potential for Q-sorters to perceive the titles as proper nouns.

6.1.3 Classifying the water-based ecosystem services in the Q-set by function

Classification of the water-based ecosystem services by function, as illustrated in Table 6.1, will facilitate the interpretation and articulation of the resulting factors. For example, certain perspectives may consider production services to be most important, and regulating services to be most unimportant. The existence of such patterns could add to the richness of the resulting viewpoints, and it may also make it easier for the investigator to convey the unique viewpoints discovered in this project to a wider audience.

All water-based ecosystem services identified for this project, except for two, could be easily classified as a production ecosystem service (e.g. oil and natural gas extraction, and mining; water for stock; and commercial irrigation), cultural ecosystem service (e.g. river-based fishing; lake/reservoir recreation; and education, management, and science), or regulating ecosystem service (e.g. biodiversity conservation, water quality, and conservation of rare plant species). One of the ecosystem services more difficult to classify was *preserving livelihoods, lifestyles and landscapes,* which refers to the benefit related to a strong agricultural community, and does so broadly, without mention of the production of goods to be sold at market. It is an ecosystem service that was motivated, as explained in Section 6.1.1, by focus group participants stressing the importance of the *culture* of agriculture. Therefore, despite the productive quality of the agricultural community, the water-based ecosystem service entitled *preserving livelihoods, lifestyles and landscapes* was classified as a cultural ecosystem service.

The second ecosystem service that was difficult to classify was *supporting of commercial land-based recreation,* which refers to the benefit associated with drawing water to support activities such as golfing, skiing, and water parks. Hein et al. (2006, p. 212, emphasis in original) defined a production service as “goods and services *produced* in the ecosystem.” The investigator’s interpretation of this definition resulted in the water-based ecosystem service for *supporting of commercial land-based recreation* to be classified as a production service because, despite the recreational aspect, there are products (i.e. golf courses, snow for skiing, and water-park rides for amusement) and their respective services are being *produced*.

6.2 The P-set

An objective of this project is to understand the full range of perspectives regarding the importance of water-based ecosystem services derived from the SNF. Therefore, the P-set attempted to represent the gamut of potential perspectives held by stakeholders in the study area. The methods used for building the P-set for this project were discussed in Section 5.2. An important aspect of data collection and construction of the P-set was deciding when the full range of perspectives regarding the importance of water-based ecosystem services had been gathered. Development of a list of potential stakeholders, presented in Table 5.2, was an ongoing process, which was facilitated by focus groups and snowball sampling. The investigator was able to collect the perspective of a stakeholder from every category except two, one of which was the Federation of Fly Fishers and the other was a specific worker within the Forest Service that will not be disclosed to protect confidentiality.

All participants in this study, which included focus groups, informal discussions, pilot testing, and data collection, were told that their responses and comments would remain confidential, which means that only the investigator and advisor of the investigator would be able to associate any data collected with the participant. By ensuring that participants' comments and viewpoints would not be attributed to them specifically, the investigator is required to present the results in a way that maintains the promised confidentiality. Consequently, Table 6.2 below represents the wide range of stakeholder interests that were collected during the Q-sorting process, but it does so in a way that makes identifying participants difficult. There are certain groups within Table 6.2 that are lumped together, which will ensure that confidentiality is maintained. For example, the participants working for federal land-management agencies are categorized by their field of expertise, but they are not associated with a specific agency. In other words, if a recreation planner working for the BLM loads onto a factor, they will be identified as a federal land manager working in recreation, without any mention of their agency.

It should be mentioned that Table 6.2 highlights the groups and interests that were recruited for participation in the Q-sort, but it does not necessarily mean that the participants completing the Q-sort were doing so with their respective organization's interests in mind. The instructions given to the Q-sorter, as discussed in Section 5.3, explicitly stressed that the preferences for various water-based ecosystem services were from the Q-sorter's perspective.

Table 6.2 Interests represented during the Q-sorting process

Sector (Number surveyed within sector) Interests/Groups (Number surveyed)	
Private Sector	**(32)**
Fishing outfitters and guides	(3)
Hunting outfitters and guides	(1)
Whitewater raft companies	(4)
Guest ranches	(1)
Farmers	(5)
Ranchers	(2)
Winter recreation enthusiasts	(3)
Summer recreation enthusiasts	(2)
Golf course/ski area employees	(2)
Mining/Gas/Oil industry	(1)
Average interested citizen	(5)
Manufacturing/industrial use	(1)
Outdoor education	(2)
Non-Governmental Organizations	**(11)**
Wyoming Outdoor Council	(2)
Wyoming Stock Growers Association	(1)
Wyoming Wilderness Association	(1)
Greater Yellowstone Coalition	(1)
Trout Unlimited	(1)
Wyoming Heritage	(1)
OHV Alliance	(1)
Wyoming State Snowmobile Association	(1)
Biodiversity Conservation Alliance	(1)
Dude Ranchers Association	(1)
Wyoming State Government	**(11)**
State Engineers Office	(1)
University of Wyoming	(2)
Cooperative Extension Services	(2)
Game and Fish Department	(1)
Wyoming Water Development Commission	(2)
Department of Environmental Quality	(1)
Department of Agriculture	(1)
State Parks	(1)

Sector (Number surveyed within sector) Interests/Groups (Number surveyed)	
Tribal Governments	**(11)**
Business council	(1)
Environmental Quality Commission	(2)
Fish and Game	(3)
Engineers Office	(1)
Water and Wastewater	(2)
Water Quality	(1)
Employment Rights Office	(1)
Local Government	**(13)**
County Commissioners	(3)
Town Mayors	(1)
Conservation Districts	(3)
Weed and Pest Districts	(2)
County Planners	(1)
Water and Sewer Districts	(1)
Irrigation Districts	(1)
Wyoming Farm Service Agency	(1)
Federal Government*	**(18)**
Recreation	(2)
Climate Change Research	(1)
Hydrology	(2)
Archeology	(2)
Silviculture	(1)
Planning	(1)
Hydropower	(1)
Plant Ecology	(1)
Soils Science	(1)
Natural Resource Extraction	(2)
Natural Resource Specialist	(3)
Biology	(1)
Total Surveyed	**(96)**

Note: *Workers from the following federal agencies completed Q-sorts, but in order to protect confidentiality the interests represented within the federal agencies will not be attributed to a specific agency: Bureau of Land Management, Forest Service, National Park Service, U.S. Fish and Wildlife Service, Bureau of Reclamation, Bureau of Indian Affairs, Natural Resources Conservation Services, and Army Corps of Engineers.

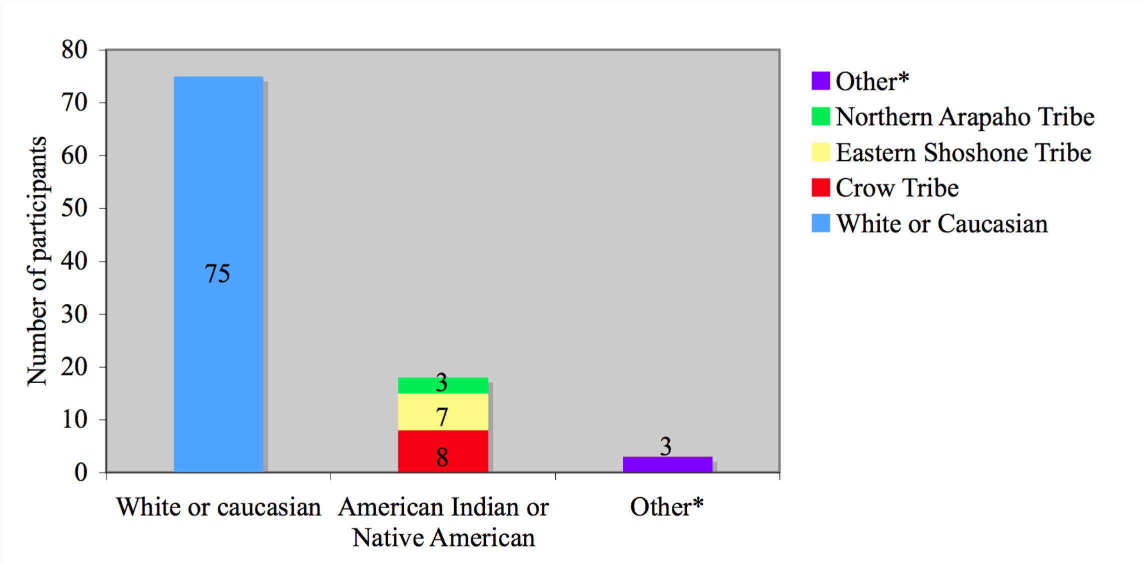
6.2.1 Demographic attributes of stakeholders

The reason for administering a demographic survey (Appendix F) during the data collection process was to provide the investigator with more information for the data analysis and interpretation process. Demographic information could potentially provide additional insight into the thought process that was taking place during the Q-sorting process. The following description of the participants was taken from a basic analysis of the demographic survey, which was completed by all those interviewed. The demographic statistics of the study sample, in many cases, will be contrasted with statistics of Wyoming, Montana, and/or the United States. The comparisons are presented not as a way to show that the study sample is representative of the greater Wyoming, Montana, or United States population (because it is not, and it was never intended to be), but it is meant to give context to the study area, which will aid interpretation of the results.

6.2.1.1 Age, race, education, and work status

Of the 96 participants interviewed: 70 were men and 26 were women. The average age was 51 years for all participants, 54 years for men, and 42 years for women, with a range in age from 26 to 88 years. Two-thirds of the participants had children. Racial diversity within the participant sample was lacking, however, it was undoubtedly due to the lack of diversity in the study area. According to the United States Census Bureau (2011), the percentage of the population that is White is 93.5% for Wyoming, and 89.9% of Montana for 2011. Figure 6.1 represents the racial diversity of the 96 participants sampled.

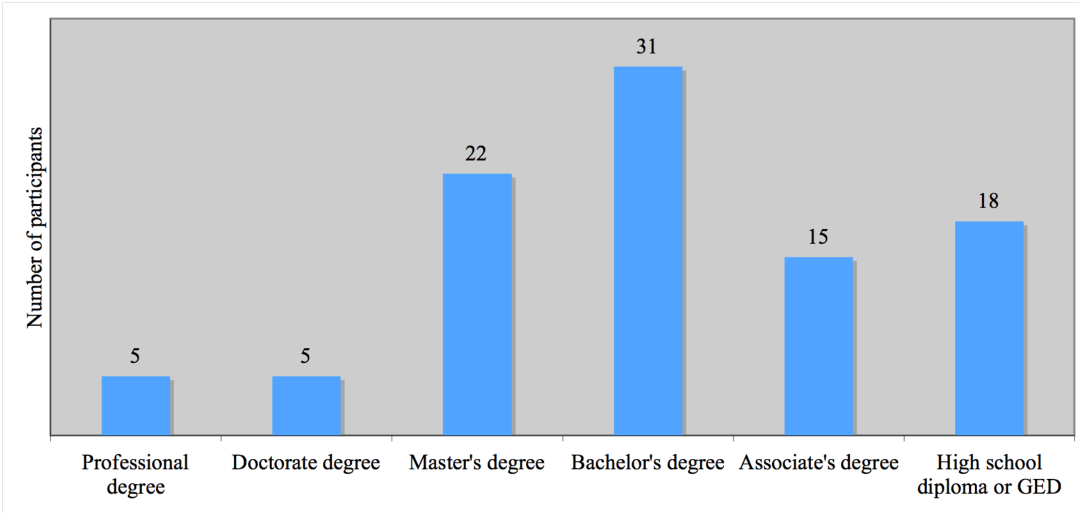
Figure 6.1 Racial breakdown of participants



*Other included three responses: "American Native," "American 100%," and "White and Mexican."

There was a wide range of education levels among participants with everyone achieving at least a high school diploma or GED. Figure 6.2 illustrates the highest level of education attained by the study sample. As a point of reference, as of 2009 and for persons at least 25 years old, 85.3% of people in the United States had achieved at least a high school diploma, 27.9% of people had achieved a Bachelor's degree, and 10.3% of the population achieved an advanced degree greater than a Bachelor's (United States Census Bureau, 2012). Compared to the U.S., the state of Wyoming has more people at least graduate high school (91.8%), but less people achieve a Bachelor's degree (23.8%) or a more advanced degree (7.9%) (United States Census Bureau, 2012). The state of Montana is comparable to Wyoming, with a 90.8% of people graduating at least high school, 27.4% achieving at least a Bachelor's degree, and 8.3% attaining a more advanced degree (United States Census Bureau, 2012).

Figure 6.2. Highest level of education achieved by participants



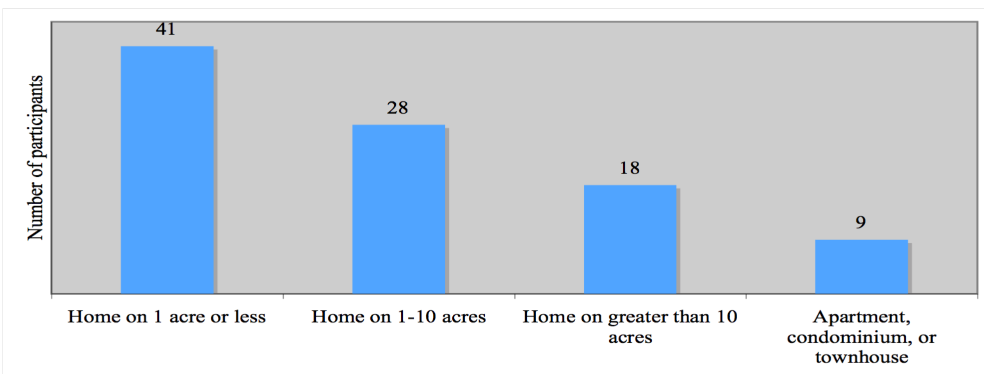
Work status was less diverse with 82 participants being employed full or part time. An additional 9 explained that they were self-employed, a business owner, or semi-retired. Only 2 participants indicated they were students, and 6 participants were in retirement. The question related to work status instructed the respondent to “check all that apply” and, as a result, the description of work status, when totaled, equals more than the 96 participants.

As discussed in Section 3.2.1, unemployment for the study area (6.44%) is high relative to the state of Wyoming (5.5%), but low relative to the U.S. (8.2%) for June 2012. As of 2011, 12.7% (72,156 residents) of Wyoming’s population are over the age of 65 (United States Census Bureau, 2011), and according to Wyoming Department of Workforce Services (2012) there are 13,349 residents (2.3% of total population) aged over 65 years that were in the workforce in 2011, which means that about 10.4% of Wyoming’s population is over 65 years old and not in the workforce.

6.2.1.2 Location of residence and type of household

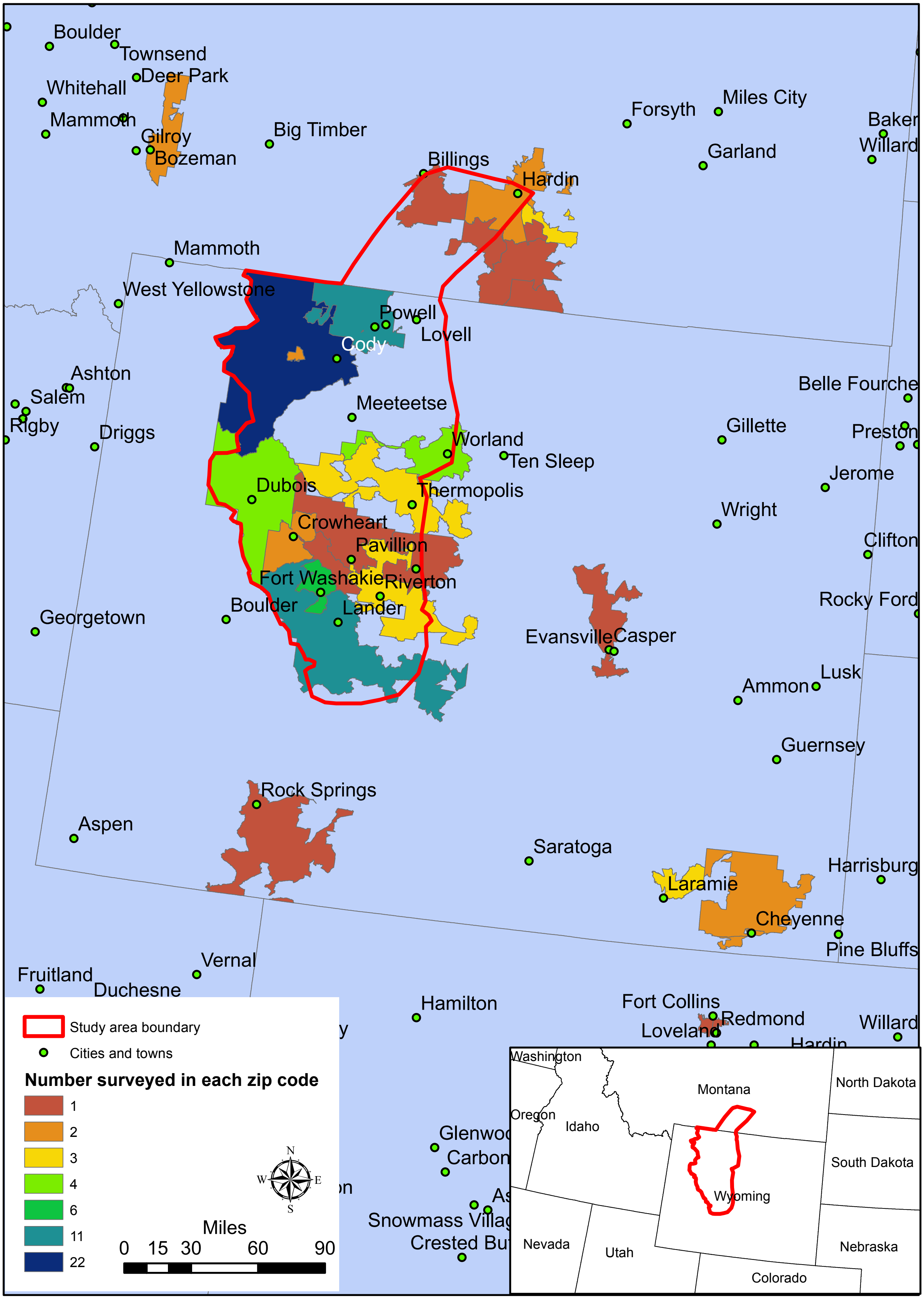
The type of home in which one resides, and the location of that residence may also be pertinent information when considering the preferences of stakeholders relating to water-based ecosystem services. For example, participants with larger plots of land may favor ecosystem services related to irrigation, or those participants living outside the study area boundaries may show a preference for ecosystem services with higher existence values. Figure 6.3 highlights the type of primary residence of participants.

Figure 6.3 Type of primary residence



The majority of the participants had primary residences within the study area; however, there were a number stakeholders living outside the boundaries of the study area. Participants spanned 31 different zip codes and 4 states. The majority of respondents were living within Wyoming: 22 participants were surveyed in Cody; 11 participants were surveyed in both Powell and Lander; 6 in Fort Washakie; and 4 people were surveyed in both Dubois and Worland. See Figure 6.4 for a map that illustrates the full overview of locations of participants, and the number of participants sampled in each location.

Figure 6.4 Map of zip codes surveyed and number of participants in each zip code

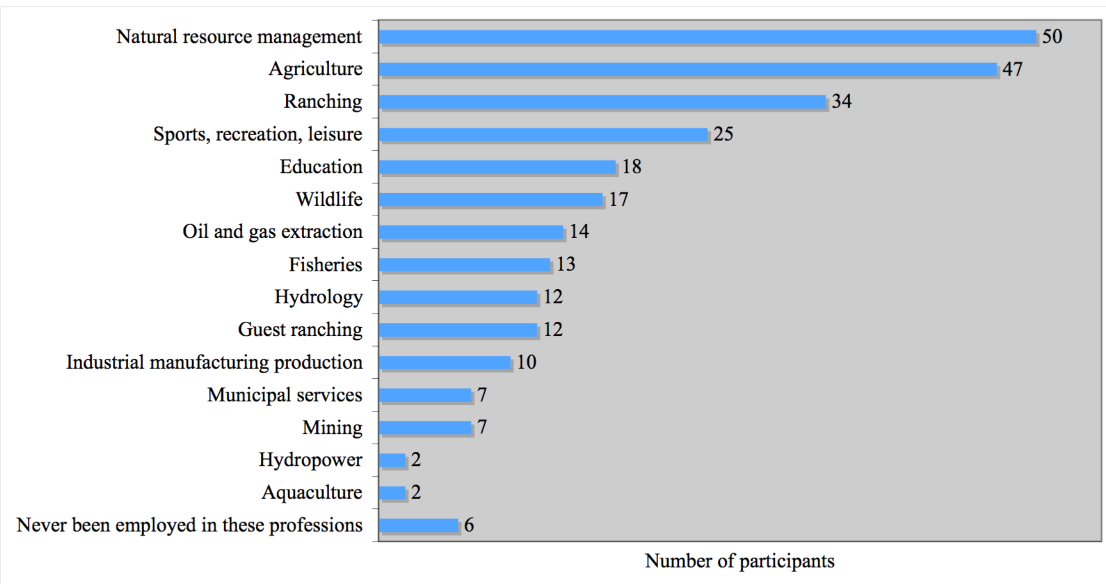


Note: There was one participant that was interviewed in the study area, but had a permanent address in Juneau, Alaska, and there was one participant that was interviewed in Missoula, Montana. Both zip codes are not featured in this map.

6.2.1.3 Work history, and membership in organizations

Understanding the participants' history of employment and their affiliation with certain types of organizations could aid interpretation, because it may turn out that certain factors are defined by participants that work in certain industries, or belong to certain organizations. There were a variety of professions and industries that participants were, or are currently, employed within, and Figure 6.5 illustrates the types of employment and the number of participants that indicated they had worked in each industry.

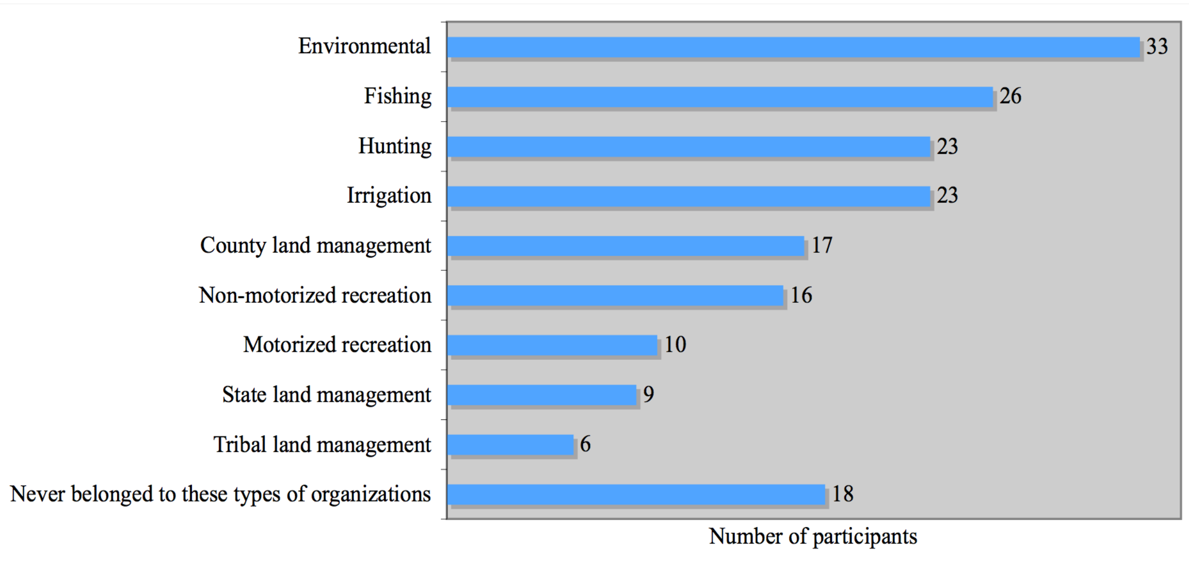
Figure 6.5 Types of employment (past and present)



Note: Respondents were instructed to "check all that apply" for their past and present employment.

The demographic survey also asked participants to provide information regarding membership to certain types of organizations, which is the information illustrated in Figure 6.6.

Figure 6.6 Types of organizations worked for or belonged to in the past or present



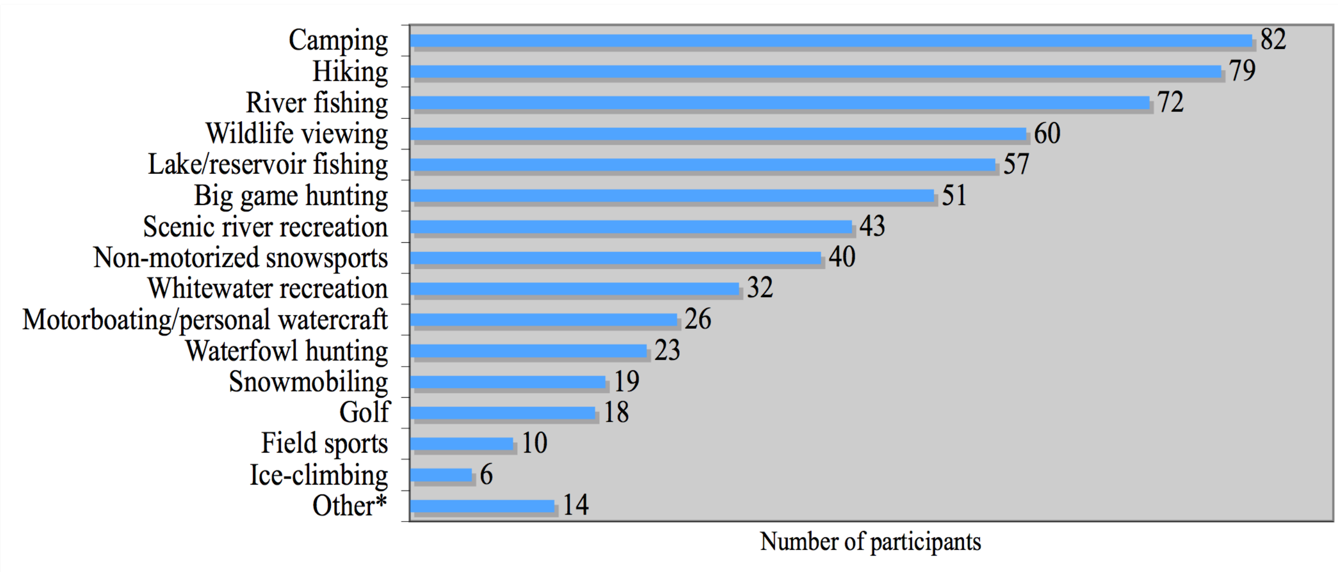
Note: Respondents were instructed to "check all that apply" for types of organizations.

It is clear from Figure 6.5 and Figure 6.6 that most of the participants surveyed have at least one connection to water, either through past or current employment or membership to a water-related or natural resource related organization. As shown in Figure 6.5, about half of the P-set have, at some point in their lives, worked in the field of natural resource management and agriculture, which may reflect the viewpoints of certain factors. Also, Figure 6.6 illustrates that about a third of the respondents have belonged to an environmental organization, and about a quarter of all respondents have belonged to a fishing, hunting, or irrigation organization.

6.2.1.4 Recreational pursuits

There are numerous water-based ecosystem services derived from the SNF that are related to recreation, and understanding the types of recreational activities pursued by participants may facilitate the understanding of the perspectives regarding the importance of the water-based ecosystem services. Figure 6.7 outlines the various types of recreational activities pursued by the study sample. The high number of respondents that participate in fishing and hunting recreational activities may facilitate interpretation of the factors.

Figure 6.7 Participation in various recreational activities

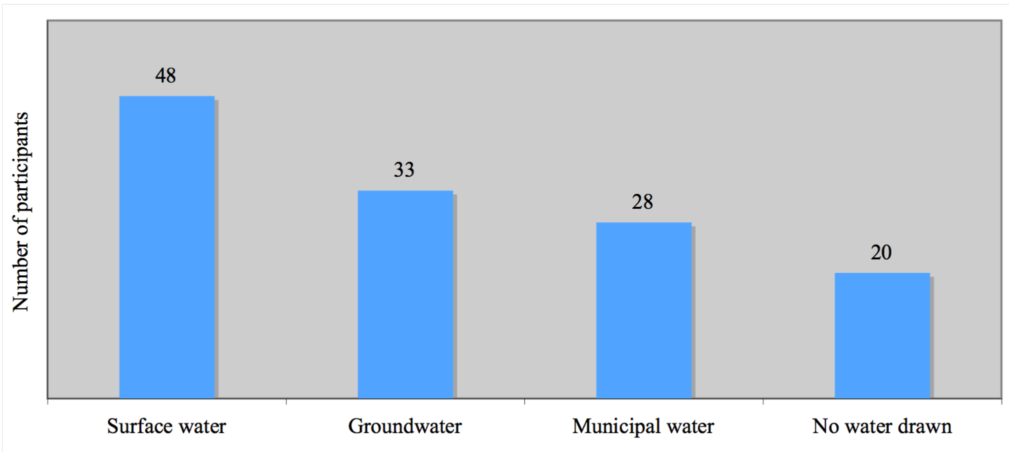


Notes: *Other recreational activities (number of participants that indicated that activity): Backpacking (3), horseback riding (1), exploring (1), cultural practices (1), shooting (1), dirtbiking (1), ATV riding (1), raquetball (1), wildlife & scenic photography (1), upland game hunting (1), running (1), sailing (1). Respondents were instructed to "check all that apply" for recreation participation.

6.2.1.5 Household and workplace supplies of water

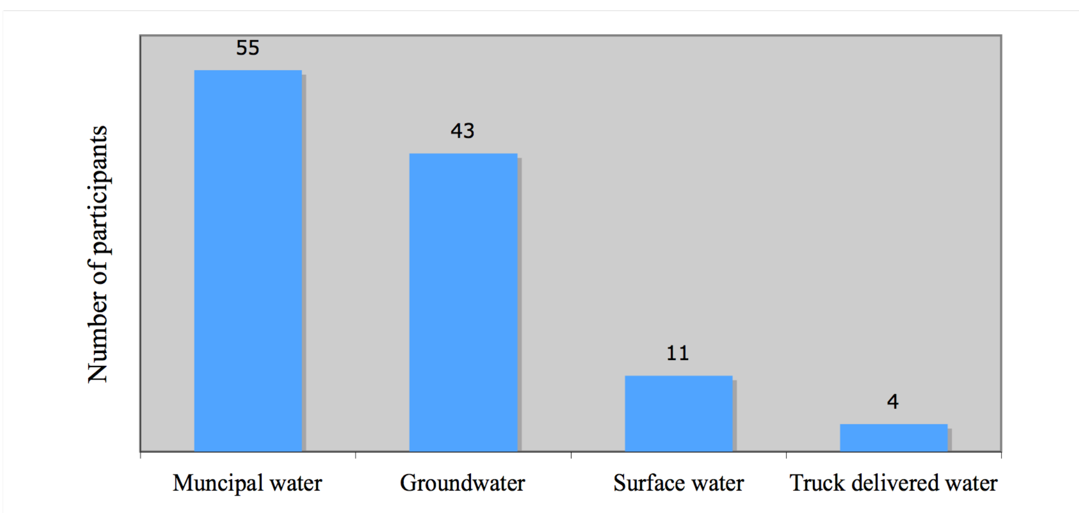
Understanding the water supplies that are relied upon by the participants in both the workplace and the household could be important. Consider, for example, a factor that is defined by participants that rely on groundwater for household use, and people that load onto that same factor feel that *oil and natural gas extraction, and mining* is an unimportant ecosystem service. It then may be possible to conclude that the unimportance of *oil and gas extraction, and mining* is due, in part, to the threat that it poses to groundwater quality. Figure 6.8 and Figure 6.9 outline the sources of water that participants rely upon for professional use, and the water supplies relied upon for household use, respectively.

Figure 6.8 Water sources used to facilitate workplace operations (past and present)



Notes: Six participants did not answer this question (Q 10), and one participant indicated they did not know if their workplace drew water for its operations. Respondents were instructed to "check all that apply" for water used for work.

Figure 6.9 Water supplies for household use



Note: Respondents were instructed to "check all that apply" for home water use.

Of the 48 participants that indicated they used surface water to facilitate workplace operations in Figure 6.8, 34 (71%) also indicated that they worked in agriculture, ranching, or both in Figure 6.5. Of the 43 participants that indicated a reliance on groundwater for household use in Figure 6.9, 36 (84%) are not relying on a municipal water source. In other words, it would be reasonable to assume that those 36 participants are being supplied by a private well. However, 3 of those 36 participants also indicated that they used surface water for household purposes. Of the 11 participants that use surface water for household use, 5 do not use a municipal water source, and 3 of those 5 also have a groundwater source. Also, all of the respondents, except for one, that indicated they used surface water for their household, also live in a house with at least one acre of land, which could mean that surface water is being used to irrigate personal property.

6.3 Results of Data Analysis

The methods used for data analysis in Q-methodology were outlined in Section 4.2.5, and the employment of those methods within the context of this project was outlined in Section 5.4. This section will present the results of the analysis of 96 Q-sorts regarding the importance of water-based ecosystem services derived from the SNF. The first subsection will discuss the process of arriving at a three-factor solution. The second subsection will discuss the three-factor solutions that result from the centroid method of factor analysis and PCA with the objective of illustrating that the two methods yield similar results, and that the centroid method provides the most useful solution for this study. The third subsection will present the results in the form of factor arrays, crib sheets and interpretive write-ups.

6.3.1 Deciding on a rotated-factor solution

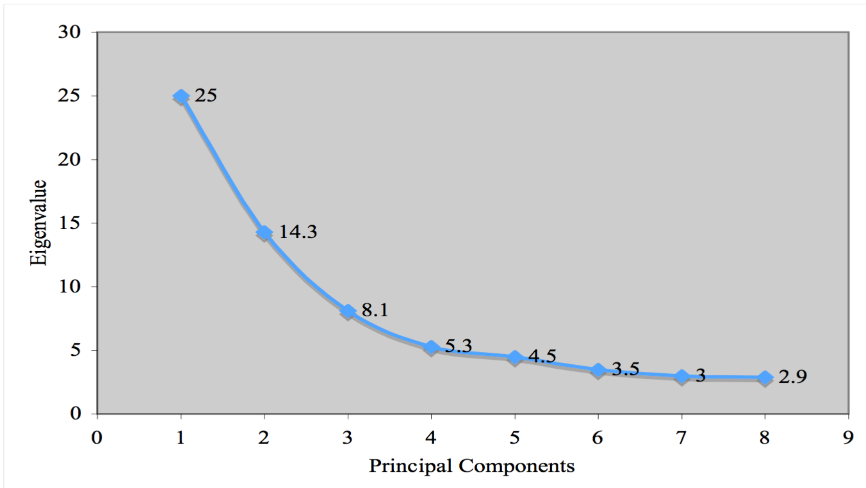
The methods used for choosing a rotated-factor solution for this project are discussed in Section 5.4.4.1. Rotation of only two factors was ruled out quickly, because rotating a larger number of factors clearly illustrated a distinct third factor, which was evident by a third factor explaining around 10 percent variance for all rotations. A six-factor rotation was not adopted because the sixth factor had only one significant loading, which is not indicative of a factor at all. Brown (1980, p. 293) explained, "if factor estimates involve only one Q-sort…we cannot separate what is common to the factor type from what is specific to the one defining individual…therefore, factors should be composed of no fewer than two variables." Watts and Stenner (2012) suggested that three or more defining Q-sorts per factor are preferable. A seven-factor rotation was not an improvement to a six-factor rotation.

After ruling out two-, six-, and seven-factor rotations, the investigator was left with deciding between a three-, four-, or five-factor solution, which is encouraging because, as Brown (1980, p. 223) asserted, "the range based on statistical criteria appears to be from two to four factors." Further use of the objective criteria could inform the decision regarding which of the three solutions to choose. Application of the eigenvalue approach was of little help because, as shown in Figure 6.10, the eigenvalue of all factors[15] was over 1.0, which is the recommended value for factor extraction. The scree test recommends that the principal component where the slope changes is the number of

[15] Figure 6.10 presents the eigenvalues for eight principal components, because the scree test was designed for PCA. However, the eigenvalues that result from centroid factor analysis are almost the same and, in all cases, are still above the value of 2.0.

factors that should be extracted and rotated. Use of the Scree test, on the SNF Q-sort data, indicated that three factors are appropriate.

Figure 6.10 Scree test applied to SNF Q-sort data



Two other objective criteria used to decide how many factors to rotate were Humphrey's rule and the significant loadings test. Humphrey's rule recommends the extraction and rotation of any factor where the product of the two highest loadings exceeds twice the standard error ($SE = \frac{1}{\sqrt{N}}$). For this study, the product of the two highest loadings for a factor would need to exceed 0.34 in order to be retained. The significant loading test recommends, at a p-level of 0.01, that at least two loadings must exceed 2.58(SE), which for this project, is 0.44. The Humphrey's rule indicated that three factors should be extracted, and the significant loadings test indicated that extracting five factors is appropriate.

The objective criteria confirmed the appropriateness of rotating three to five factors, but it did not give the investigator a definitive answer as to what rotation is best (such is the nature of Q-methodology). Therefore, several statistical considerations, as discussed in Section 5.4.4.1, were employed to decide which factor-solution was the best fit for interpretation.

Also, the investigator developed Table 6.3 as a visual aid for deciding between a three-, four-, or five-factor solution. Table 6.3 illustrates the defining Q-sorts (those positively-pure Q-sorts and negatively-pure Q-sorts are marked with an "X" or an "N", respectively), the confounding Q-sorts (those Q-sorts that are marked with a "C"), and the null Q-sorts (those Q-sorts that are unmarked) for each factor in the case of a three-, four-, and five-factor solution. By presenting the data in such a way, the investigator was able to understand how the different factor solutions would impact the distribution of defining Q-sorts, confounding Q-sorts, and null Q-sorts. For example, Participant 65 loaded significantly onto the fourth factor in a four-, and five-factor solution, but did not significantly load onto any factor in a three-factor solution. Also, consider Participant 21 who loaded purely onto factor one in a three-factor solution, but becomes confounded in a four- and five-factor solution. Table 6.3 also clearly shows the variance explained for each factor solution and the number of Q-sorts that define each factor for a three-, four-, and five-factor solution.

Table 6.3 Layout of defining Q-sorts for a three-, four-, and five-factor solution

	Factor 1			Factor 2			Factor 3			Factor 4			Factor 5		
Factors rotated	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Subjects															
1				X	X	X									
2	X	X	X												
3	X	X	X												
4			C	C	C		C	C	C						
5				X	X	X									
6				X	X	X									
7				X	X	X									
8		X	X												
9	X	X	X												
10				X	X	X									
11	X	X	C												C
12	X	X	X												
13	X	X	X												
14	X	X	X												
15	X	X	X												
16	X	X	X												
17			X												
18					X	X									
19				X	X	X									
20				X				X	X						
21	X	C	C					C							C
22				X		C			C						
23					C	X	N	C							
24				X	X	X									
25				X	X	X									
26															
27	X	X	X												
28							N								
29					X	X									
30				X	X	X									
31				X	X	X									
32															
33				X	X	X									
34	C	C	C	C	C	C									
35				X	C	C		C							C
36				X											
37	X	X	X												
38	C	C	C	C	C	C									
39				X	X	X									
40					X	C	N					C			
41					C	C	N	C	C						
42	X	X	X												
43				X	X	X									
44				X	X	X									
45				X	X	X									
46				X	X	X									
47							X	X	X						
48				X					X						
49															
50	X	X	X												
51	X	X	X												
52	C	C	C				C	C	C						
53	X	X	X												
54	X	X	X												
55	X	X	X												
56				X	X	X									
57							X	X	X						
58	C			C	N	N									
59							X	X	X						
60	X	X	X												
61	X	X	X												
62	X	X	X												
63															

64	X	X													
65			C								N	N			C
66				X	X	X									
67															
68	X	X	X												
69				X											X
70	C	X	X	C											
71	X	X	X												
72				X	X	X									
73	X	X	X												
74															
75	X	X	X												
76				X		C					X	C			
77							X	X	X						
78	C	C	C				C	C	C						
79											X	X			
80							N								N
81							X	X	X						
82												X			
83															
84							X	X	X						
85							X	X	X						
86							X	X	X						
87				C			C	X	C						C
88	X	X	X												
89	X	X	X												
90	X	X	X												
91	X	X	X												
92	X	X	X												
93	X	X	X												
94	X	X	X												
95	X	X	X												
96	X	X	X												
Explained Variance	22%	22%	22%	16%	15%	15%	10%	10%	9%	NA	5%	5%	NA	NA	6%
Number of defining Q-sorts	35	36	35	26	23	23	13	10	10	NA	3	3	NA	NA	2

Note: An "X" is indicative of a pure-positive loading Q-sort, an "N" is indicative of a pure-negative loading Q-sort, and a "C" is indicative of a confounding Q-sort.

In the end, the investigator deemed a three-factor solution to be the most appropriate for a number of reasons. The first reason was factor reliability, and a three-factor solution yielded factors that were more reliable than a four- or five-factor solution. A factor's reliability, as discussed in Appendix B.9, is positively correlated with the value of the difference in standard error between two factors, which impacts the statements that are deemed statistically distinguishable. The reliability of a factor is a function of the number of defining Q-sorts, and the standard error "serves to locate the probable range within which true factor scores are expected to be found" (Brown, 1980, p. 298). Therefore, a relatively unreliable factor will have a larger standard error, which means that more error will have to be accounted for when interpreting the resulting factor array. Table 6.4 exhibits the reliability of the factors for a five-, four-, and three-factor solution.

Table 6.4 Reliability scores of each factor for a three-, four-, and five-factor solution

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Five-factor solution	0.993	0.989	0.976	0.923	0.889
Four-factor solution	0.993	0.989	0.976	0.923	
Three-factor solution*	0.993	0.990	0.970	0.952	

Note: *The three-factor solution presents a reliability score for a fourth factor because it is bipolar. The fourth factor is actually one of two distinct viewpoints that exist on the third factor, and each viewpoint has a reliability score because each viewpoint was flagged separately to create a factor array.

As shown in Table 6.4, the reliability of the fourth factor for a four- and five-factor solution is lower than the reliability of the alternative viewpoint on the third factor. The lower reliability on the third factor of a three-factor solution (positive viewpoint) relative to the third factor in a four- and five-factor solution is preferable, according the investigator, because of the much higher reliability of the fourth factor (negative viewpoint that will be explained below) in a three-factor solution relative to the fourth factor in both a four- and five-factor solution.

The second reason a three-factor solution was adopted is related to interpreting factors that have both positive and negative loadings, which are known as bipolar factors. Interpretation of bipolar factors can be done in two ways: (1) calculate two separate factor arrays[16] using the positive loadings for one array and the negative loadings for another array; or (2) take the mirror image of the factor array, which results from having

[16] Creating two separate arrays involves the flagging of the significant positive loadings on the original factor, and the flagging of the negative loadings on the same factor (which has been inverted so that all positive loadings are rendered negative and all negative loadings are rendered positive). In other words, the same factor is flagged twice (but separately), which creates two separate arrays.

both significant positive and negative loadings used as defining Q-sorts, to represent the perspective of those that load negatively onto the factor. Brown (1980, p. 253) explained when these two options are most appropriate, "In studies composed of more realistic numbers of subjects, bipolar factors which emerge are frequently defined by several *Q* sorts at both ends; In these cases, rather than report one factor only, the negative end merely being a reflection of the positive end, it is generally advisable to create separate factors to represent the poles."

Use of the mirror-image approach is appropriate when there is only one negative loading (or one positive), because creating a separate array for one Q-sort would yield a factor that is really not a factor at all, but more of an idiosyncratic viewpoint. Using the mirror-image approach when there are multiple loadings at each pole can potentially misrepresent the two viewpoints, because there may be statements that both poles agree on, which is nuance that is lost by employing the mirror-image approach. Mattson et al. (2006, p. 395) explained, "bipolar loadings can mask important nuances in how participants on one end or another associate with statements and with other factors. To circumvent this difficulty, we forced the groups lying at opposite ends of the bipolar factors to be represented by two separate factors." It is important to note that this quote is a bit misleading because, even though there are two resulting factor arrays, they do not represent different factors per se but, instead, they represent two distinct viewpoints that exist on the same factor. This is an important point when considering variance explained, which remains the same for both manifestations of the same factor. For example, the third factor in this study had thirteen loadings, eight positive and five negative, which only described 10 percent of the study variance total, despite being presented via two separate factor arrays.

For this project, as shown in Table 6.3, a five-factor solution yielded a fourth and fifth factor with three and two factor loadings, respectively. The fifth factor had one positive loading and one negative loading, which makes interpretation difficult because such factors may be more representative of two idiosyncratic viewpoints, as opposed to a group of shared views (a factor). The fourth factor, in a four-factor solution, had three loadings with one of those loadings being negative, which may also be an idiosyncratic viewpoint and not a true factor. Watts and Stenner (2012) prefer to keep factors that have three or more significant loadings, and even though factor four of a four-factor solution has three loadings, there are only two positive loadings and one negative loading. In contrast, the third factor in a three-factor solution has eight positive loadings and five negative loadings, which allows the investigator to create separate factor arrays for each viewpoint, resulting in a more nuanced interpretation. In short, the bipolar third factor in a three-factor solution allows for a better interpretation than the bipolar factors that are yielded by a four- and five-factor solution.

The third aspect of the rotated solutions that can indicate which solution is *most appropriate* relates to the explained variance. Brown (1980, p. 209) asserted that, "an important characteristic of the final set of factors is that they should account for as much of the variability in the original correlation matrix as possible." The five-, four-, and three-factor rotation account for 57 percent, 52 percent, and 48 percent of study variance, respectively. Despite Brown's (1980) recommendation to find a solution that explains the most variance, the five- and four-factor solutions were not chosen for the reasons outlined above, and the 48 percent of variance explained by a three-factor solution is still adequate. Kline (1994) noted that any solution that explains 35-40 percent of the study variance is considered to be a sound solution.

Another aspect of the three factor-solutions that the investigator should consider is the distribution of both the confounding and the null Q-sorts (discussed in Section 4.2.5.6). Table 6.5 was constructed using the information in Table 6.3, and it illustrates the distribution of pure, confounding, and null Q-sorts across a three-, four-, and five-factor solution.

Table 6.5 Distribution of pure, confounding, and null Q-sorts

	Number of factors in each solution		
Types of Q-sorts	Three	Four	Five
Pure	74	72	73
Confounding	8	9	14
Null	14	15	9
Total Q-sorts	96	96	96

Even though only the pure Q-sorts are used to define the factor arrays, the confounding Q-sorts can still be explained in terms of the resulting factor arrays. As a result, the confounding Q-sorts can be seen as a combination of two or more viewpoints that exist within the chosen factor solution instead of being interpreted as idiosyncratic viewpoints (null Q-sorts). For example, a three-factor solution has 8 confounding Q-sorts and 74 pure Q-sorts, which means that 82 of the 96 participants can be explained in terms of the three factors. The remaining 14 participants (null Q-sorts) are indicative of those that have viewpoints that are not explained by the three factors, but are instead specific to those participants. The solution with the lowest number of null Q-sorts suggests that it is a solution with the fewest idiosyncratic viewpoints in the P-set. If the investigator employed this reasoning, then the five-factor solution would have been adopted. Despite this, the investigator did not employ a five-factor solution because the lower amount of null Q-sorts in a five-factor solution is offset by a higher number of confounding Q-sorts. A higher number of confounding Q-sorts suggests that a five-factor solution has more participants that embody at least two of the existing viewpoints, but it does not mean that there is necessarily another distinct viewpoint that exists (factors 4 and 5 not robust). Also, this is a good time to reiterate that there is not one specific consideration that would result in one factor solution being chosen over another and, therefore, the investigator considers the three-factor solution to be the *most appropriate* solution for this study.

6.3.2 Results of factor analysis and principal components analysis

As stated in Section 4.2.5.3 on the extraction of the initial factors, factor analysis and principal components analysis (PCA) yield similar results, even though PCA is considered to have the ability to explain the greatest amount of variance. This section will present the results of the analysis of 96 Q-sorts using the centroid method of factor analysis and PCA. The data was analyzed using the computer program PQMethod.

As explained above, a three-factor solution was adopted using the centroid method, which explained 48 percent of the study variance and had 74 participants helping to define four separate factor arrays. A three-factor solution resulted in four factor arrays because the third factor was bipolar, with multiple loadings at each pole. The three-factor solution that resulted from PCA only explained a single percentage point more (49%) study variance than centroid analysis. Also, using the same flagging criteria for both PCA and centroid method, the PCA solution had one less participant, in total, defining the three resulting factors, which means relatively less reliable factors overall. Table 6.6 illustrates the results of both the centroid approach and PCA with the variance explained and the number of defining Q-sorts for each factor.

Table 6.6 Results: Centroid approach vs. PCA

Method	Centroid approach				Principal Component Analysis (PCA)			
Factors	1	2	3	Total	1	2	3	Total
Variance Explained	22%	16%	10%	48%	22%	16%	11%	49%
# of Defining Q-sorts (participants)	35	26	13*	74	37	25	11*	73

Note: *The third factor using both approaches is bipolar with 8 positive loadings and 5 negative loadings for the centroid approach, and 6 positive loadings and 5 negative loadings for PCA.

The comparison in Table 6.6 shows the similarity between the results for both approaches, and the similarity also exists for the factors that result. In fact, there are very few differences between the factors that result from PCA and the factors that result from centroid analysis. In addition to the centroid method being the chosen approach of reputable Q-methodologists like Brown (1980) and Watts and Stenner (2012), the investigator feels that centroid method is preferable because of factor reliability. In PCA, the third factor (positive viewpoint) has a factor reliability of 0.960, which is lower than the reliability of the same factor (.970) using the centroid method. The reliability of all other factors are the same, including the first factor which has two more significantly loading Q-sorts using PCA. The unchanged reliability, despite the difference in loading

Q-sorts, is due to the nature of averages. An average of a large number of variables is more difficult to influence than an average of a small number of variables.

6.3.3 Interpretation and articulation of the three-factor solution

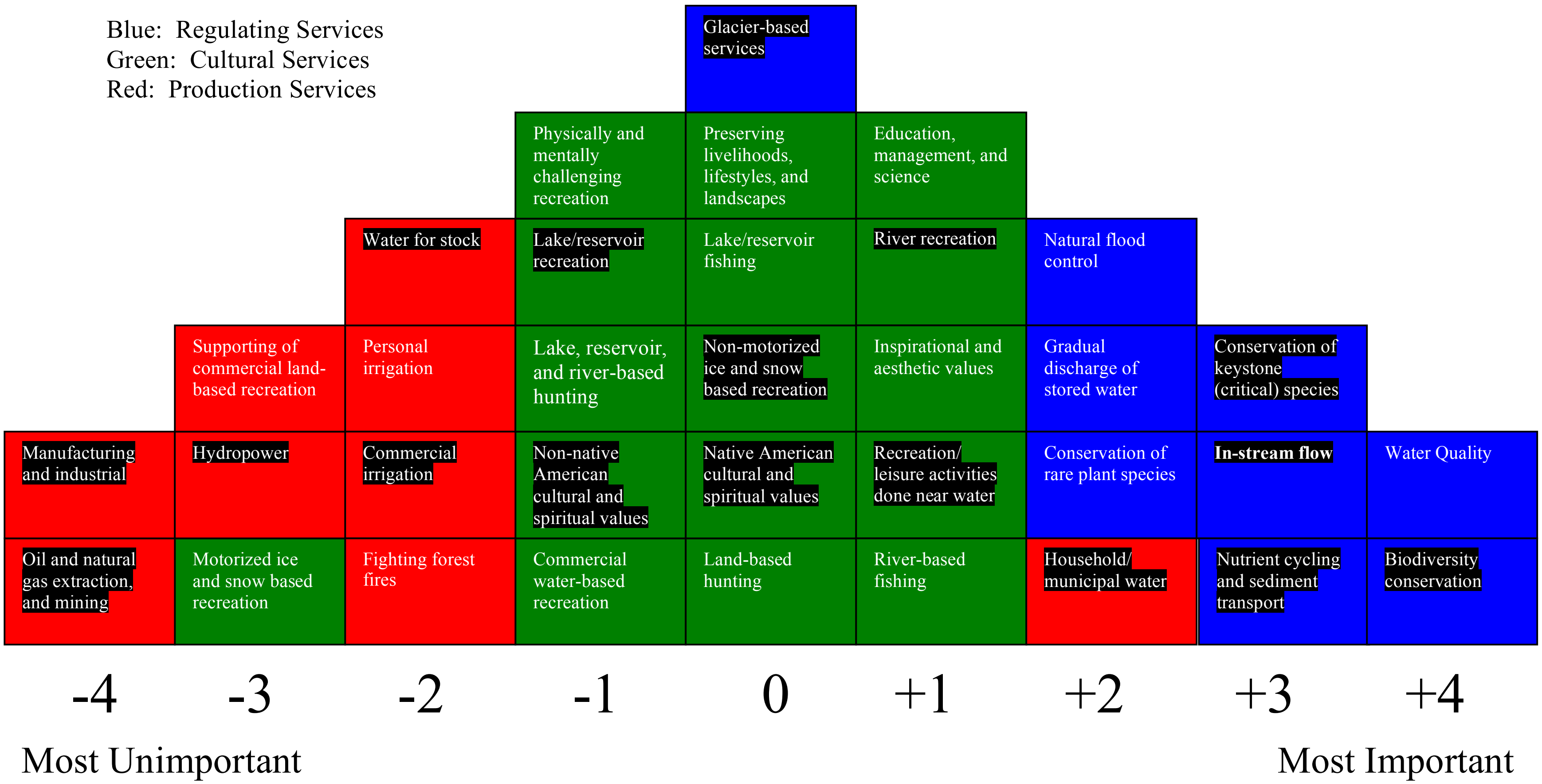
The three-factor solution that resulted from factor analysis of 96 Q-sorts will be interpreted and articulated in this section, the methods for which are discussed in Section 5.4.5. Factor analysis yielded a three-factor solution that, because of a bipolar third factor, resulted in four distinct viewpoints. The viewpoints were named the environmental perspective, agricultural perspective, Native American perspective, and recreation perspective. It is important to pay close attention to the statistically distinguishable statements and those statements that are in the crib sheets. Within the interpretive write-ups, the statistically distinguishable statements will be bolded and the crib-sheet statements will be italicized.

6.3.3.1 Factor 1: the environmental perspective

Factor 1 explains 22 percent of the study variance and is defined by 35 significantly-loading participants (20 male participants and 15 female participants). The average age of the participants that load onto the first factor is 47 years. Fourteen participants work in natural resource management or natural resource science for the state, local, or federal government, and seven participants work for environmentally based non-profits. Of the remaining 14 participants that load onto factor 1: six work for, or own, commercial recreation outfits; two work in outdoor education; one works as an ecologist; one works as an environmental specialist in the oil and gas industry; one owns a farm; one works in local government; one works as an administrator for a high school in the study area; and one is retired.

Figure 6.11 is the factor array for the first factor, which is developed from the factor scores. By examining Figure 6.11, it becomes clear that the environmental perspective is named as such because of the preference for regulating services, however, this viewpoint could also be known as the 'reluctant consumer perspective'. The suitability of both names becomes evident when considering that eight out of the nine ecosystem services ranked -2 and below are production services (those in red) and, according to the reluctant consumer perspective, certain production services may impact the flow and quality of certain regulating services (those in blue), which are eight out of the nine ecosystem services ranked +2 and above for the first factor. Five of the unimportant production services are statistically distinguishable (as opposed to four of the important regulating services), which means that the reluctant consumer perspective may be more defined by what is unimportant than what is important.

Figure 6.11 Factor array 1



Note: Those ecosystem services highlighted in black are statistically distinguishable

Table 6.7 is the crib sheet for factor 1, and it highlights additional water-based ecosystem services that may be in need of special attention. The statistically distinguishable statements, and the overall picture, presented in Figure 6.11 are effective in illustrating that the environmental perspective generally sees the regulating services as important and the production services as unimportant. The crib sheet, though, creates a comparison between the environmental perspective and all other perspectives, which can help to highlight ecosystem services that may not be statistically distinguishable, but are nonetheless valuable for creating a clear portrayal of the viewpoint.

For example, the crib sheet shows that the environmental perspective has a higher preference for the conservation of rare plant species (not statistically distinguishable), conservation of keystone species (statistically distinguishable), and biodiversity conservation (statistically distinguishable) than all other perspectives. Therefore, it becomes clear that the environmental perspective not only considers certain regulating services as important, they consider them as *more* important than all other perspectives. Another interesting aspect highlighted by the crib sheet for factor 1 is the relatively low ranking assigned to household/municipal use of water, which is statistically distinguishable. Without the crib sheet, the investigator might not have realized that household/municipal use was only statistically distinguishable for the environmental perspective.

Table 6.7 Crib sheet for factor 1

Statements ranked +4 in factor array 1
Water Quality
Biodiversity Conservation
Statements ranked higher in factor array 1 than in all other factor arrays (score)
Biodiversity conservation (+4)
Conservation of rare plant species (+2)
Conservation of keystone species (+3)
Nutrient cycling and sediment transport (+3)
Recreation/leisure activities done near water (+1)
Statements ranked lower in factor array 1 than in all other factor arrays (score)
Oil and natural gas extraction, and mining (-4)
Manufacturing and industrial (-4)
Water for stock (-2)
Commercial irrigation (-2)
Household/municipal water (+2)
Hydropower (-3)
Personal irrigation (-2)
Statements ranked -4 in factor array 1
Oil and natural gas extraction, and mining
Manufacturing and industrial

Water quality (+4) is paramount for the environmental perspective because, if kept pristine, it can trickle down and positively influence a suite of other ecosystem services. Participant 14 explained,

> The quality of water…[could impact] cutthroat trout [i.e. ***conservation of keystone species (+3)***]; we have a reputation around here for being a world class, if not world class then national, fishing destination and the cutthroat trout has a huge profile, and because of that if we lose one or more of those species it is going to significantly alter the ecosystem.

The environmental perspective also regards the *conservation of rare plant species (+2)* as important because, as Participant 92 suggested, "a lot of the plants haven't even been identified or studied…[and] I see a lot of benefit to knowing about them because maybe they are going to be helpful down the line as things change." The importance assigned to the conservation of rare plants by the environmental perspective may be due, in part, to the high concentration of peatlands in the study area, many of which have not been inventoried and are potential sites for the discovery of unknown plant species (discussed in Section 3.1.2).

Water quantity left in the river, or ***in-stream flow (+3)***, according to Participant 50, is crucial for the health of the river:

> We lose some of these streams that run dry, and then you lose that water quality. Water quality is threatened and then the biological diversity is threatened, and even the human use of that stream is threatened. So when I think of in-stream flow, I think of basically a full healthy stream that can move its water and move its sediment and maintain its morphology.

A human use supported by in-stream flow, which is important for the economy of the study area (Section 3.2.3.2) and the environmental perspective, is river-based fishing (+1). Participant 15 elaborated,

> I think the particular area of your interest [study area] has a lot of nice rivers, and I think the ability for us to use the resources we need to maintain a good healthy river environment…[which can] provide the opportunity for people to fish and, I think, the river-based fishing opportunity is sinking. Gradually we are losing more of it across the country; it is in high demand and I think we ought to protect [it].

The environmental perspective values natural flood control (+2), which can maintain a healthy river by providing “a lot of natural filtration that needs to occur in the water as it comes from snowmelt and sheetwash over the land before entering the riparian system. And so, say for example, that you do not have a robust vegetative strip along that river then you are getting sediment laden water going directly into the river” (Participant 3).

A sediment laden river can impact opportunities for ***recreation and leisure activities done near water (+1)*** because, as Participant 11 remarked, “when the water starts going down it crystals up and it is just so beautiful, you can see the trout in there, people love that.” Also, the gradual discharge of stored water (+2) is important for whitewater enthusiasts, who, according to Participant 11, “always worry about snowpack” negatively influencing opportunities for **river recreation (+1)**. The environmental perspective appears to prefer recreational activities that, in most cases, are quiet and without much danger, which is evident by the low importance assigned to motorized ice and snow based recreation (-3), and physically and mentally challenging recreation (-1).

The environmental perspective values nature untrammeled by man, and inspirational and aesthetic values (+1) may be harder to realize on reservoirs, which could explain the negative, or zero, importance assigned to all ecosystem services related to reservoirs. Participant 27 stated, “the really cool thing about the North Fork [of the Shoshone River] is it is almost all wilderness, so there is not a chance for them to mess it up too bad, because you are above the reservoir. Almost all of the water that comes into this drainage comes out of the wilderness.”

Even though ***oil and natural gas extraction, and mining (-4)*** provide economic stimulus to the study area, the environmental perspective regards it as a threat to many of the regulating ecosystem services (those in blue). Consider the comment by Participant 93, "If we have increased oil and gas production on the Shoshone, I think there is possibility with extracted water and effluent holding ponds and that kind of thing…you know, the entire extraction process has the ability to disrupt appropriate ***[nutrient] cycling and sediment transport" (+3)***." In addition, ***biodiversity conservation (+4)*** is threatened by "oil and gas development, [which can] have the impacts of produced water[17] and that type of thing impacting those habitats" (Participant 93). Those who adopt the environmental perspective value education, management, and science (+1) because land management, according to Participant 92, "shouldn't just be a series of protocols and formulas that are not based on some truth and reality on how systems work."

The unimportance of agricultural ecosystem services like ***commercial irrigation (-2)***, and ***water for stock (-2)*** is partly due to the threat it presents to healthy river systems, which can support activities like fishing. For example, Participant 13 bluntly stated

> The people that control in-stream flow, control whether we have good fishing or not; good aquatic insect hatches or not; whether we have a healthy river at all...at this point I see us having really bad in-stream flows, [which are] inconsistent from year to year, very poorly managed, short-

[17] Produced water refers to the water that results from oil and natural gas extraction, which must be managed in some way. Produced water can be stored in effluent ponds, or treated and discharged onto the landscape. See Section 3.3.3 for a discussion on produced water.

sighted and made for irrigation of agricultural goods and services and that is it.

Furthermore, Participant 51 declared, “the thing we worry about most for **in-stream flow (+3)** would be the development of it for commercial [i.e. ***manufacturing and industrial use (-4)***] or agricultural interests, potentially residential.” The reluctant consumer perspective cannot stress enough that “things like the oil industry, with fracking going on, in my mind it is the kind of thing that eventually we will find that it is going to screw up the water. Land use, whether it is the timber industry, farming, agriculture definitely impact water” (Participant 16). ***Hydropower (-3)*** is also unimportant to the environmental perspective, the generation of which can have impacts on the in-stream flow and riverine ecosystems.

Land use and management of certain resources are within human control, and the relative unimportance of **glacier-based services (0)** compared to the other regulating services may be due to a feeling related to the inability to impact the fate of the glaciers. For example, Participant 27 asked rhetorically, “that is not something that we can affect is it?...You know, it is one of those things that I do not think man controls it. If I could control it, I would say lets not have those glaciers running out.”

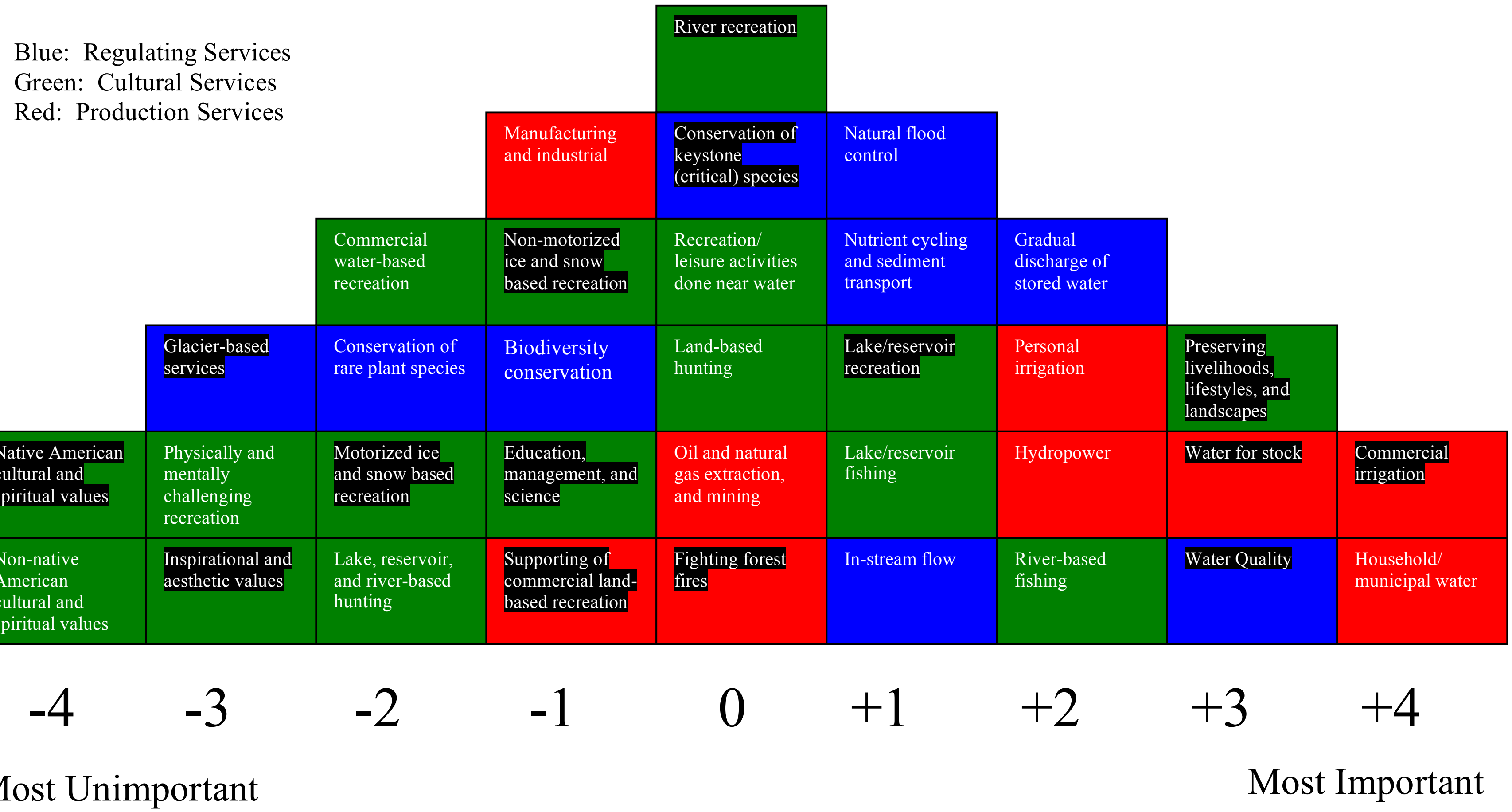
Supporting of commercial land-based recreation (-3), and *personal irrigation (-2)* are also unimportant to the reluctant consumer perspective. Despite the feeling that consumptive uses are unimportant, the environmental perspective realizes the need for human consumption of water for everyday living and, as a result, view *household/municipal* *water (+2)* as important. However, it should be noted that a value of +2 assigned to household/municipal water is the lowest value assigned to this ecosystem service in any of the four factor arrays.

6.3.3.2 Factor 2: the agricultural perspective

Factor 2 explains 16 percent of the study variance and is defined by 26 significantly-loading participants (21 men and 5 women). The average age of the participants who load onto the second factor is 54 years. Seven of the participants who loaded onto factor 2 were natural resource managers or scientists at the federal, local, or state level. Six of the participants worked as farmers or ranchers, and one participant worked for the USDA Farm Service Agency. Of the remaining twelve participants, there were two county commissioners, one ranching-based non-profit worker, one tourism-based non-profit worker, four interested citizens, an economist, a manufacturer that relies on the agricultural industry, a hydropower worker, and an employee of the Wyoming Water Development Commission.

Figure 6.12 is the factor array for the second factor, which illustrates the high level of importance to the four ecosystem services related to agriculture (commercial irrigation, water for stock, personal irrigation, and preserving livelihoods, lifestyles and landscapes). The agricultural perspective was named as such mostly because of their preference for the agricultural based ecosystem services, but the importance assigned to the regulating services that support agricultural needs (i.e. water quality, gradual discharge of stored water, and natural flood control) also supported the name.

Figure 6.12 Factor array 2



Note: Those statements highlighted in black are statistically distinguishable

Table 6.8 is the crib sheet for factor 2, and it reinforces the appropriateness of the agricultural-perspective name assigned to the second viewpoint. The four agricultural-based ecosystem services are more important for this viewpoint than all other viewpoints. Even though personal irrigation is not statistically distinguishable for the agricultural viewpoint, it is still ranked higher in their factor array than in all others.

Table 6.8 Crib sheet for factor 2

Statements ranked +4 in factor array 2
Commercial irrigation
Household/municipal water
Statements ranked higher in factor array 2 than in all other factor arrays (score)
Commercial irrigation (+4)
Preserving livelihoods, lifestyles, and landscapes (+3)
Water for stock (+3)
Personal irrigation (+2)
Statements ranked lower in factor array 2 than in all other factor arrays (score)
Physically and mentally challenging recreation (-3)
Native American cultural and spiritual values (-4)
Glacier-based services (-3)
Inspirational and aesthetic values (-3)
Statements ranked -4 in factor array 2
Native American cultural and spiritual values
Non-native American cultural and spiritual values

According to some participants, agriculture is the lifeblood of the study area and, without ***water for stock (+3)***, "people would be forced to look outside the area or region for stock, so it would drive prices up" (Participant 10). Those that subscribe to the agricultural perspective rely on **water quality (+3)** and quantity to maintain healthy agricultural communities, which ***preserve livelihoods, lifestyles and landscapes (+3)***. Participant 44 explained, "the quality of water and the quantity that has been supplied off the forest, and historically livelihoods have been developed. Agricultural communities, everything we do, the reason we live where we do is because of the water running off the mountains. Being a headwater state, that is just the nature of the beast." Participant 45 also noted that if there isn't enough water, "then those of use that depend on irrigation to produce crops and water for livestock would have to reduce our income basically, because that is how most of us make our income."

The high quality water running from the headwater streams in the study area also enhances the everyday use of water for drinking and other *household/municipal uses (+4)*. Having clean water from the start is comforting for both economic and personal reasons. Participant 6 noted, "having a good clean source of water, even though it can be cleaned up within the system…it is just the fact that the cleaner it is before it goes into the plant, the better I feel about it regardless of the total outcome, and cheap [too], because it does not cost as much to clean up the water."

The agricultural perspective considers in-stream flow (+1) as somewhat important, which may be because it supports river-based fishing (+2) and **water quality (+3)**. The reason for such a conclusion is that in-stream flow can potentially conflict with more important ecosystem services like ***commercial irrigation (+4)*** and *personal irrigation (+2)*. The state of Wyoming considers in-stream flow to be a beneficial use for environmental reasons. In other words, a water right can be appropriated for the good of the environment. Participant 39 noted, "there is an awful lot of different opinions, and negative opinions about in-stream flow having a water right."

Other ecosystem services that the agricultural perspective sees as competing with irrigation are biodiversity conservation (-1) and the conservation of rare plant species (-2). Participant 31 commented, "increased pressure from conservation groups, fishing, in-stream flow and anything like that would influence the ability to use it for commercial irrigation." Those that adopt the agricultural perspective also stress the extra benefit of hydropower (+2), which is a secondary function of the system of dams in the study area, and it is tied to the agricultural use of water. Participant 43 explained, "The primary purpose of the [hydropower] plants here are to generate what power we can to meet irrigation demands. We generate both at Boysen and Buffalo Bill, but that same water is used at Yellowtail. So I don't know how you capture that benefit, but it keeps getting used over and over"

Those who align with the agricultural perspective are not anti-environment, and they know it is hard to cultivate green fields without regulation services such as gradual discharge of stored water (+2) and, for those that are not downstream of a man-made dam, natural flood control (+1) is crucial. The system of dams within the study area assuages many of the concerns about water availability, which may be why ***glacier-based services (-3)*** are unimportant despite their support of late-season flow.

The agricultural perspective understands that conservation-based regulating services are not the only ecosystem services perceived as a threat to agricultural water needs. Participant 39 suggested, "all the water is appropriated, but the only thing you can do is shift the beneficial uses from agriculture, to industrial [i.e. manufacturing and industrial

(-1)], to municipal." Although not explicitly expressed, the consumptive use of water for supporting of commercial land-based recreation (-1) is potentially another threat to the water that is required by those who adopt the agricultural perspective.

Those benefits that are less tangible such as ***inspirational and aesthetic values (-3)***, *non-native American cultural and spiritual values (-4)*, and ***Native American cultural and spiritual values (-4)*** are seen as the most unimportant. The unimportance of spiritual and cultural values derived from water may stem from spiritual beliefs being biblical, and not related to the land. Participant 6 noted, "my basic religious beliefs do not include any activities outside of the church buildings." In addition to water-based cultural and spiritual beliefs being hard to relate to for the agricultural perspective, they are also another reason to regulate the use of the water for something other than agriculture. Finally, the statistical significance of the unimportance of the Native American cultural and spiritual values could stem from a long history of conflict over the allocation of water between Whites and Indians.

Those who subscribe to the agricultural perspective, like everybody else, need to escape the daily grind somehow, and river-based fishing (+2), lake/reservoir fishing (+1), and **lake/reservoir recreation (+1)** provide that relief. The agricultural perspective regards the adrenaline rush and testing of one's abilities through *physically and mentally challenging recreation (-3)* as unimportant, and recreational pursuits done in the ice and snow, both **motorized (-2)** and **non-motorized (-1)**, are unimportant; perhaps they are a young-persons game. The importance assigned to recreational activities related to fishing, lakes and reservoirs may be indicative of the second factor being defined by relatively older respondents (54 years), because these recreational activities are typically less strenuous.

In the end, the agricultural perspective doesn't see commercial irrigation as a threat to the water but, instead, it creates an economy for the study area, and preserves the history of the study area. Participant 35 eloquently stated:

> I think it is important to understand that we are dependent on this commercial irrigation, though, I do not think of myself as a commercial irrigator. It is a huge enterprise, it is what we are dependent on. We would live in a desert valley if it were not for that, and all of the service industries that serve us like the fuel guy, the fertilizer, all the dealers that supply seed; they would have to be gone because we would not be here. Then you got the parts man, and the guy that fixes the tractor, and the guy that owns the tractor shop, the guy that services my pickup, there are just so many spin-offs of that. In ways too, it is just part of the history. We are in the museum cultural center [referring to the site of the interview] here in Hot Springs County, you look around and almost all of the; you look at the old photos and there is a doctor, but he also had a ranch. Or there is a dentist and he had, or there is a cobbler and they had a place up Owl Creek. They are all dependent on [commercial irrigation], so it is woven into a web.

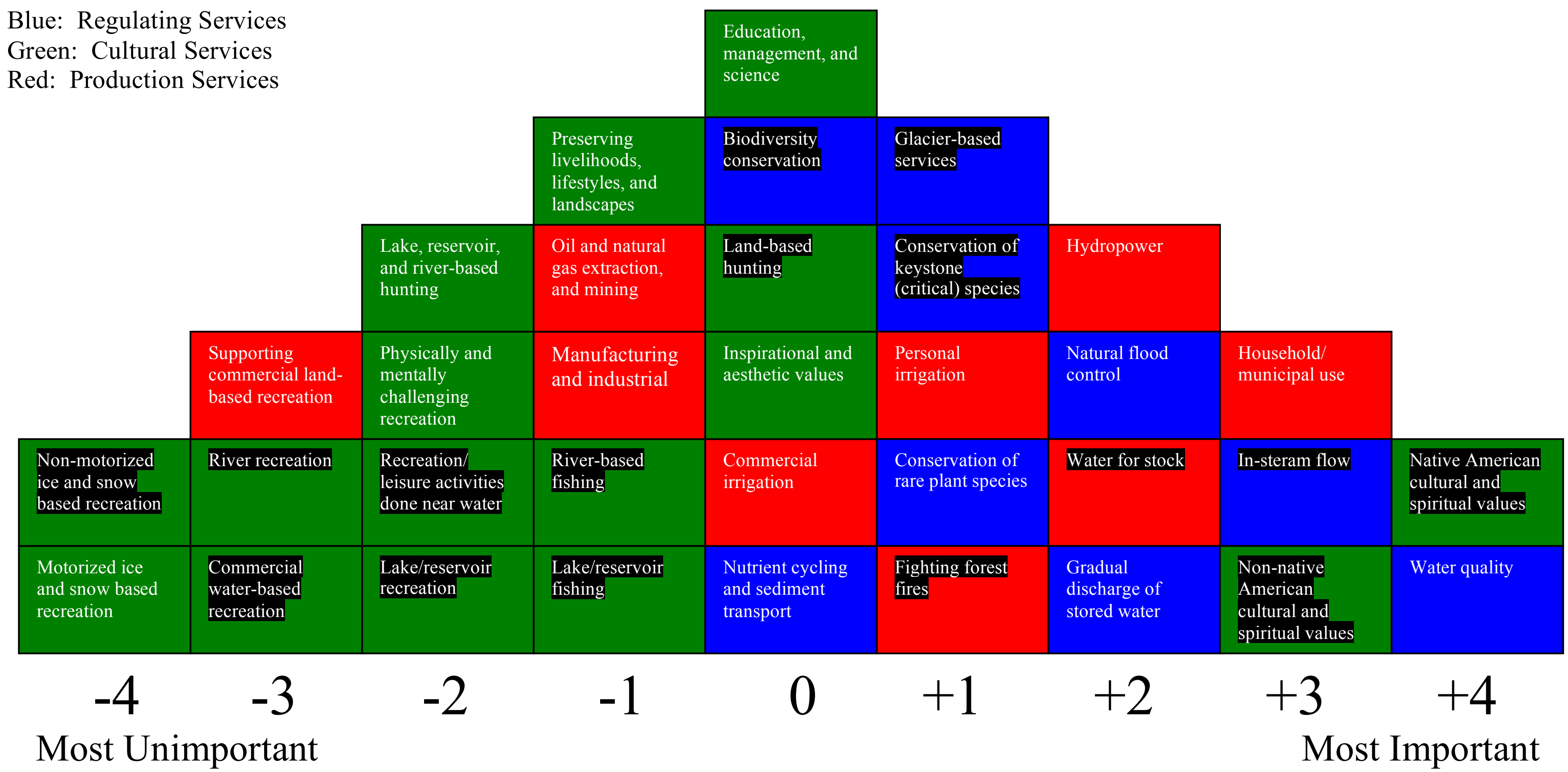
The agricultural perspective is a traditional viewpoint that, as discussed in Section 3.3, could be the result of the study area being settled by early European-Americans with the mission of developing agriculture.

6.3.3.3 Factor 3A: the Native American perspective

The Native American perspective was one of two distinct viewpoints that loaded onto the third factor, which explained 10 percent of the study variance. Factor 3A was defined by 8 significantly-loading participants (7 men and 1 woman). The average age of the participants is 54 years. All eight participants who loaded onto factor 3A are Native Americans from either the Eastern Shoshone Tribe or the Crown Indian Tribe. Seven of the participants work for their respective Tribal governments in some capacity, either in natural resource management, or municipal water management. The one remaining participant who loaded onto factor 3A is a Tribal member that has a job outside of the tribal government.

Figure 6.13 is the factor array for the positive manifestation of the third factor. This viewpoint was dubbed the Native American perspective because of the high level of importance assigned to Native American cultural and spiritual values. This viewpoint could alternatively be named the non-recreator perspective, because of the negative importance assigned to 11 of the 12 recreation-based ecosystem services, 7 of which are statistically distinguishable. The Native American perspective also illustrates that all but two regulating services are positively important.

Figure 6.13 Factor array 3A



Note: Those statements highlighted in black are statistically distinguishable

Table 6.9 is the crib sheet for factor 3A, which highlights certain ecosystem services that deserve special attention, such as the relatively high level of importance assigned to non-Native American cultural and spiritual values. It indicates that even though the Native American perspective does not have any personal connection to non-Native American cultural values, there is a certain level of respect embodied by this viewpoint for all cultural and spiritual values derived from water, regardless of them being for the Native or non-Native. Also, the unimportance of recreation-based ecosystem services to the Native American viewpoint, which is highlighted in Figure 6.13, is reinforced by the fact that 7 of the 8 ecosystem services in the "statements ranked lower in factor array 3A than in all other factor arrays" category of the crib sheet are recreational ecosystem services.

Table 6.9 Crib sheet for factor 3A

Statements ranked +4 in factor array 3A

- Native American cultural and spiritual values
- Water quality

Statements ranked higher in factor array 3A than in all other factor arrays (score)

- Native American cultural and spiritual values (+4)
- Glacier-based services (+1)
- Fighting forest fires (+1)
- Non-native American cultural and spiritual values (+3)

Statements ranked lower in factor array 3A than in all other factor arrays (score)

- Preserving livelihoods, lifestyles, and landscapes (-1)
- Commercial water-based recreation
- Non-motorized ice and snow based recreation (-4)
- River recreation (-3)
- River-based fishing (-1)
- Motorized ice and snow based recreation (-4)
- Lake/reservoir recreation
- Recreation/leisure activities done near water
- Lake/reservoir fishing

Statements ranked -4 in factor array 3A

- Non-motorized ice and snow based recreation
- Motorized ice and snow based recreation

Native American cultural and spiritual values (+4) are sacrosanct to those who align with the Native American perspective, and are integral in their lives. Participant 77 explained, "Our way of governing, our way of teaching, our love for each other came from that River corridor…that is our stories, we come out of the water." *Water quality (+4)* supports many of the cultural ceremonies like the Sacred Sweat. Participant 85 elaborated, "It has been with the Crow Indians for a long time, the so called 'Sweat', and it is very important. When you have no place to sweat or dip [in the river] after that, you do not want to dip in the river so that affects that, you know, the pollution that goes into that river." ***In-stream flow (+3)*** is also important for Native American cultural and spiritual values. Participant 57 asserted that, "if they are going to lower the water, we have less water for the plants and, so, that causes a shortness of growth for our natural plants that we use culturally."

The Native American perspective regards both an intact natural resource for cultural and spiritual purposes, and the maintenance of privacy and character of special cultural sites as important. However, both aspects, which support Native American cultural and spiritual values, are threatened by the expansion of recreational opportunities. Participant 84 noted, "If Bighorn Recreation Area is developed, yeah, it is going to affect our cultural sites in that area. The Lovell…Transpark road, [a proposed road], goes right through the heart of our prime hunting grounds." In general, recreation is unimportant to the Native American perspective, and the most unimportant is *motorized ice and snow based recreation (-4)*. As the popularity of ***non-motorized ice and snow based recreation (-4),*** ***commercial water-based recreation (-3)***, ***river recreation (-3)***, supporting of commercial land-based recreation (-3), ***lake/reservoir recreation (-2)***, ***recreation/leisure activities done near water (-2)***, and physically and mentally challenging recreation (-2) continue to increase, the threat to developing recreational opportunities increases, which can affect cultural sites. Another reason why recreation may be unimportant to the Native American perspective is cost, which, depending on the recreational activity, can be quite high. For example, Table 3.3 puts the price of a day of fishing at $36 for a resident of the Basin and, according to Figure 3.2, the median household incomes of the two Indian Reservations in the study area are significantly lower than averages for Wyoming, Montana, and the United States as a whole.

Also, the importance of revenue generating ecosystem services like hydropower (+2), and **water for stock (+2)** may be a reflection of the tough economic times for those who subscribe to the Native American perspective. For the Crow Indians, the Water Settlement Act provides funding for the development of agriculture and hydropower. Participant 81 explained:

> Right now the Crow Nation received a water settlement…we have the right to develop a hydroplant right here at the Afterbay and, so, there are so many kilowatts of power that can generate and the Crow Tribe can do whatever hey wish with that resource. Whether to provide local subsidized, maybe lower prices, or they can sell if they can get on a grid.

A healthy environment is important to those who align with the Native American perspective because, traditionally, it means they are salubrious too. Participant 85 commented:

> The old timers say that when, they viewed the snow that comes and falls, or the snow that melts and runoff, they think it suppresses disease. And this year, for example, there seems to be a lot of coughing and sneezing and wheezing and we have not got a whole lot of snow. I think they look at it from that standpoint, the weather was extremely important part of the day to day living and the values.

Therefore, for the Native American perspective, certain regulating services (those in blue), such as gradual discharge of stored water (+2), conservation of rare plant species (+1), **conservation of keystone species (+1)**, and ***glacier-based services (+1)*** are important because they reflect a healthy environment, which is synonymous with their own health.

Fighting forest fires (+1) is more important for the Native American perspective than all other factors. Participant 86 stated:

> Just knowing how much damage [forest fires] could cost, and just having that access to water and even having the storage to water. I was just thinking damage control, because I can see how much of a problem that it is…like years ago we would see these helicopters and they would come down and they would get water right from the river and they would haul it to the fire and release it. It was neat that they just had that access to water.

In the end, it all comes back to water quality and the importance of household/municipal water (+3), which according to Participant 85, a Crow Tribal member, has "always been somewhat polluted with things that can be detrimental, and we really haven't fixed it." The situation is similar for residents of the Wind Indian Reservation, according to Participant 47:

> A lot of what tribes and we are concerned about more than anything is what is coming over the mountain. The reservation is a class one watershed, and you have got Jona Field…the big gas [oil and natural gas extraction, and mining (-1)] play over there, two to three thousand wells and what falls out of a lot of the pollution that comes over the mountain. We get a lot of acid rain, and the Wind River Mountains don't buffer a lot of those pollutants.

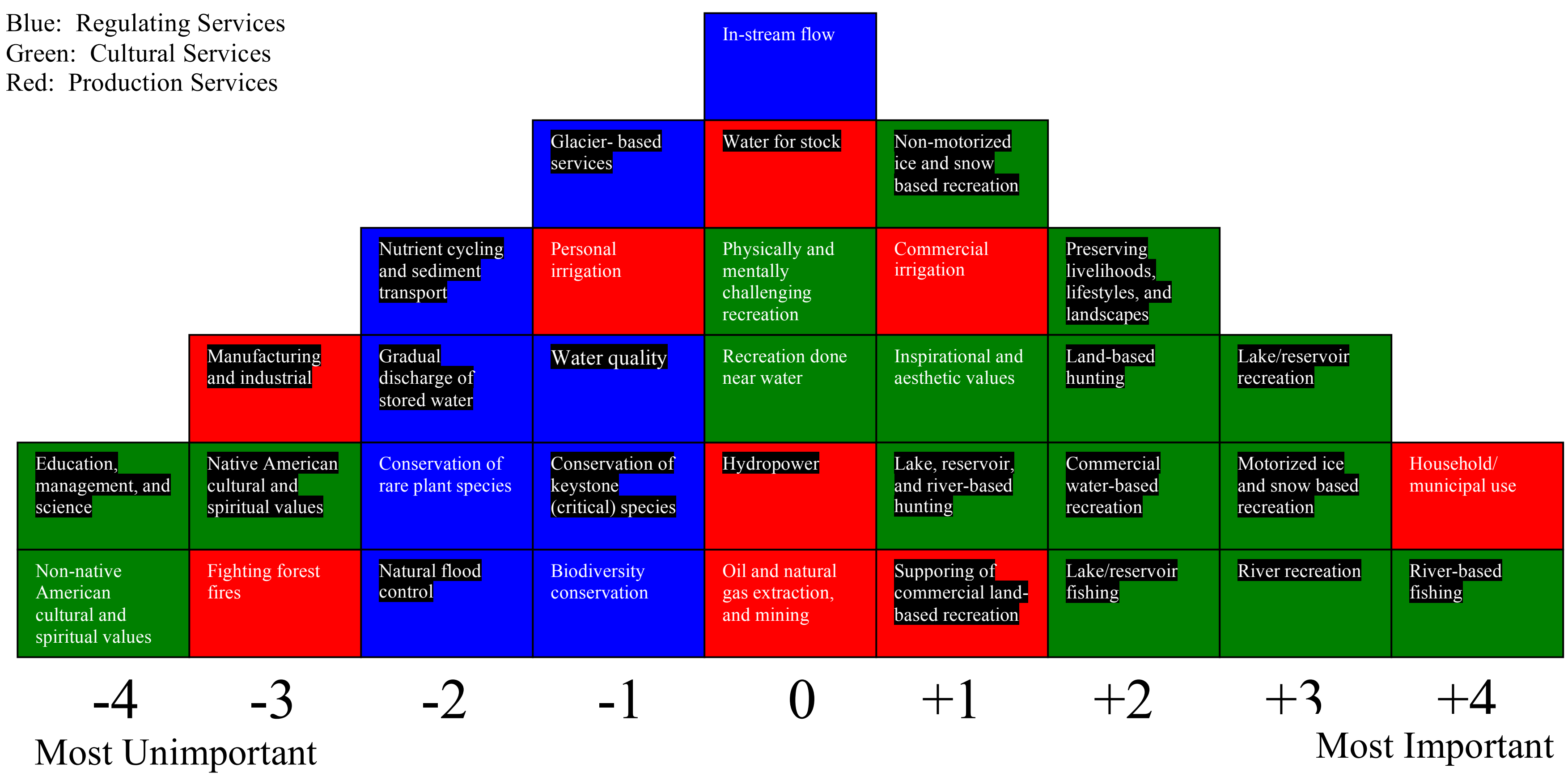
The concerns related to water quality could also explain the unimportance assigned to manufacturing and industrial use of water (-1) by the Native American perspective.

6.3.3.4 Factor 3B: the recreation perspective

The recreation perspective was the second of two distinct viewpoints that loaded onto the third factor, which explained 10 percent of the study variance. Factor 3B was defined by 5 significantly-loading participants (all men). The average age of participants who loaded on factor 3B is 45 years. Four of the five participants who loaded onto factor 3B were associated with recreation: two were donating their time to support motorized recreation, one works as a hunting guide and skiing guide, and one worked as a raft guide. The last participant owned his own business, and was a county commissioner.

Figure 6.14 is the factor array for the negative manifestation of the third factor, which is named the recreation perspective for the high level of importance assigned to those ecosystem services related to recreation. The recreation perspective regards almost all types of water-based recreation as important, which is reflected by 10 out of 12 recreational ecosystem services being ranked as positively important (all of which are statistically distinguishable). On the other side, the recreation perspective sees regulating services as unimportant, which is reflected by all but one of them being negatively important.

Figure 6.14 Factor array 3B



Note: Those statements highlighted in black are statistically distinguishable

Table 6.10 is the crib sheet for factor 3B, and it reinforces the importance of recreation-based ecosystem services for the recreation perspective above all other viewpoints. There are 12 recreational-based ecosystem services in the Q-set, and 11 of them are ranked higher by the recreation perspective than all other viewpoints. The crib sheet also illustrates the relative unimportance of several regulating services, with 6 out of the 9 regulating services being ranked lower by the recreation perspective than all other viewpoints.

Table 6.10 Crib sheet for factor 3B

Statements ranked +4 in factor array 3B
Household/municipal use
River-based fishing
Statements ranked higher in factor array 3B than in all other factor arrays (score)
Commercial water-based recreation (+2)
Land-based hunting (+2)
Non-motorized ice and snow based recreation (+1)
River recreation (+3)
River-based fishing (+4)
Physically and mentally challenging recreation (0)
Motorized ice and snow based recreation (+3)
Lake, reservoir, and river-based hunting (+1)
Lake/reservoir recreation (+3)
Supporting of commercial land-based recreation (+1)
Lake/reservoir fishing (+2)
Statements ranked lower in factor array 3B than in all other factor arrays (score)
Water quality (-1)
Education, management, and science (-4)
Fighting forest fires (-3)
Conservation of keystone (critical) species (-1)
Nutrient cycling and sediment transport (-2)
Natural flood control (-2)
In-stream flow (0)
Gradual discharge of stored water (-2)
Statements ranked -4 in factor array 3B
Education, management, and science
Non-native American cultural and spiritual values

Those who align with the recreation perspective are eager to take advantage of the exceptional recreational opportunities provided by the study area's water resources. Participant 23 remarked:

> Most of my water thing is recreating, I just, my boys are more into hunting [i.e. ***land-based hunting (+2)***; ***lake, reservoir, and river-based hunting (+1)***] nowadays, and most anything you do hunting around here that has got to be some water. Whether you are hunting pheasants and sage chickens and that sort of thing…and the fishing [i.e. ***river-based fishing (+4)***; ***lake, reservoir fishing (+2)***] and that sort of stuff.

Motorized water-based recreation activities (***i.e. motorized ice and snow based recreation (+3)***, ***lake/reservoir recreation (+3)***) are viewed as a boon to the economy, by the recreation perspective, because of the required fuel stops and the expenses associated with the machines. Participant 41 noted, "the recreational users, especially the ones that have motorized vehicles, they usually have a little bit more expendable money." Also, motorized recreational uses are seen as a way to generate money for federal land management agencies. Participant 41 asserted:

> [Motorized users] already pay $15 dollars per vehicle to use on federal land, and we are the only user that does, is motorized. Hikers, horses, mountain bikers don't have to pay to use the land, but we do, and that money sits in a fund and the Forest Service isn't drawing from the fund because they didn't want to apply it. There is a $2 million budget in Wyoming right now to use for OHVs, and that is growing by 15% every

> year, and that fund it is not being utilized because the Forest Service isn't applying it. If I was the Forest Service I would be hiring an OHV manager, paying his salary to help manage to build these trails, manage these trails, because we are already paying for it but we are not getting any use out of it, and we are required to pay that fee even though it doesn't do us any service.

Those who view recreation negatively are active in voicing their opposition, which may be why Participant 41, at first, tersely answered, "environmentalists, [and] management" when asked what factors or influences would impact his ability to receive motorized ice and snow based recreation. When asked to elaborate about this specific threat to expanding recreational opportunities on the forest, Participant 41 remarked, "We can't get the trails generated. A lot of these trails were existing 20 or 30 years ago, and then they closed them due to the roadless acts or grizzly reasons or whatever, and once it gets taken away it doesn't ever come back, even if the circumstances are changed, we cant get them back."

Therefore, it is reasonable to attribute the unimportance assigned to ***Education, management, and science (-4)*** by those who subscribe to the recreation perspective to their concern that it will usually find a way to decrease recreational opportunities on the Forest. Either because extra trails lead to greater sediment in the water, which management asserts has an impact on ***water quality (-1)***, or some ideal landscape is closed off to recreation for the **conservation of keystone (critical) species (-1)**. Those who embody the recreation perspective do not understand the push to regulate activities such as snowmobiling because, as Participant 40 noted, “snowmobiles; we stake our trail on top of snow, when the snow is gone you don’t even know we have been there.”

At the forest level, those who adopt the recreation perspective support multiple uses of resources and less management. Participant 41 declared, “The more management you have the more politics that you have, so, what happens is the Forest Service is going broke. The reason why is because they do not use their resources anymore, and there are reasons why they have done it. But, if you don’t have mining or logging, you don’t have funding for recreation or anything.” Perhaps the money spent on *fighting forest fires (-3)* could be spent on expanding recreational opportunities on the forest. The recreation perspective may have ranked fire suppression lower than any other factor, because they disagree with the current allocation of management resources.

In general, the recreation perspective assigns negative importance to the ecosystem services that support a healthy environment. For example, 8 out of 9 regulating services (those in blue) are of negative importance to the recreator. The regulating service not negatively ranked is *in-stream flow (0)* (which is ranked lower than in any other factor array), and its relatively high importance (compared to other regulating services in factor array 3B) may be due to its direct support of important water-based ecosystem services like ***river-based fishing (+4)***.

Those who align with the recreation perspective regard economic opportunity as important, which is why they support the agricultural community. A healthy agricultural community can **preserve livelihoods, lifestyles, and landscapes (+2)**. Those who adopt the recreation perspective also acknowledge the importance of boosting the economy through recreation with exceptional populations of big game for hunting (***land-based hunting*** *+2*), a water supply to ***support commercial land-based recreation (+1)***, and a beautiful resource for ***commercial water-based recreation (+2)***. However, according to Participant 80,

> In most cases I would say recreation takes the bottom hand when it comes to the economic side of things…so if anything comes up with any kind of, if it is **hydroelectric power (0)**, anything with commercial fishing, or irrigation those are going to prohibit a lot of things that I enjoy doing for rafting, kayaking [i.e. ***river recreation (+3)***], fishing, and that kind of thing. It is going to be switching, with the dams [i.e. *in-stream flow (0)*] and the salmon migration kind of deal [i.e. biodiversity conservation (-1)] it is going to flip and flop, back and forth.

Those who identify with the recreation perspective value connecting with nature and feel there is an opportunity for quality family time during recreational pursuits. In other words, the recreation perspective believes that there is a cultural and spiritual experience to be had outdoors during recreation activities, which is why managing for **Native American cultural and spiritual values (-3)** and *non-Native cultural and spiritual values (-4)* separately is unimportant.

6.3.3.5 Non-defining participants

As illustrated in Table 6.5, the three-factor solution that was adopted for this project consisted of 74 pure Q-sorts, 8 confounding Q-sorts, and 14 null Q-sorts. The 74 pure Q-sorts helped to define the four viewpoints articulated above. This section will discuss the remaining 22 Q-sorts that did not help to define the four viewpoints by highlighting some of their demographic data, as well as some of their perceptions regarding the importance of water-based ecosystem services.

The remaining 22 Q-sorts consisted of 17 men and 5 women with an average age of 54 years, which is higher than the average age of 51 years for the entire P-set. Fourteen of the 22 remaining participants identified as White or Caucasian, and 8 were enrolled members in the Northern Arapaho, Eastern Shoshone, or Crow Indian Tribe. The level of educational attainment for the remaining 22 Q-sorts was similar to that of the entire sample (a Bachelor's degree was the most common level of educational attainment). The remainder of the information gathered from the demographic survey was similar for the 22 non-defining participants when compared to the P-set as a whole.

Of the 8 confounding Q-sorts: 5 were confounding on the environmental perspective and the agricultural perspective; 2 were confounding on the agricultural perspective and the Native American perspective; and 1 was confounding on the environmental perspective and the Native American perspective. The five participants who were confounding on the environmental perspective and the agricultural perspective were all men, and two worked for a tribal government in the study area (one of these confounding participants loaded negatively onto the agricultural perspective and positively on the environmental perspective), one worked in the local government, one worked in the state government, and one owned a guest ranch in the study area. The two participants who were confounding on the agricultural perspective and the Native American perspective were men. One worked for an irrigation district in the study area and one worked in land management at the state level. The one participant who was confounding on the environmental perspective and the Native American perspective was a male that worked for a tribal government in the study area.

The 14 null Q-sorts were comprised of 9 men and 5 women who worked in a diverse range of professions: 4 worked for Federal land management agencies; 3 worked for a tribal government in the study area; 3 worked for recreation outfits; 2 worked in the Wyoming state government; 1 worked for a non-profit; and 1 owned a farm in the study area.

The 8 confounding Q-sorts can be explained in terms of a combination of two of the four viewpoints, and the 14 null Q-sorts can be considered to have idiosyncratic viewpoints that are not significantly explained by any of the four viewpoints. As to be expected, inspection of the 14 null Q-sorts highlighted individual perspectives that were different from the four factor arrays explained above. A few of the stark contrasts were the importance of inspirational and aesthetic values, fighting forest fires, and physically and mentally challenging recreation, none of which were important in the four defined viewpoints.

In order to more fully understand the remaining 22 Q-sorts, the investigator conducted a separate centroid factor analysis with varimax rotation of the 22 Q-sorts. This yielded two factors, which will be referred to as factor A and factor B (as opposed to factors 1, 2, 3, and 3A described above). See Appendix I for the z-scores and corresponding ranks of each water-based ecosystem service for factors A and B. Factor A was defined by 7 of the 22 participants, five of which were those participants that were previously confounding on factors 1, 2, and 3. Not surprisingly, factor A is a hybrid of the environmental perspective (factor 1), agricultural perspective (factor 2), and Native American perspective (factor 3). For example, the nine most important ecosystem services for factor A (+2 to +4 on the Q-board) are as follows: household/municipal water (+4); water quality (+4); preserving livelihoods, lifestyles, and landscapes (+3); conservation of keystone species (+3); in-stream flow (+3); commercial irrigation (+2); biodiversity conservation (+2); natural flood control (+2); and gradual discharge of stored water (+2). Inspection of the factor arrays for the environmental perspective, agricultural perspective, and Native American perspective shows that each of these nine ecosystem services is within the +2, +3, or +4 column of at least one of the factor arrays.

On the other side of the Q-board, factor A considers the following nine ecosystem services as unimportant: oil and natural gas extraction, and mining (-4); non-native American cultural and spiritual values (-4); motorized ice and snow based recreation (-3); manufacturing and industrial (-3); lake, reservoir, and river-based hunting (-3); physically and mentally challenging recreation (-2); land-based hunting (-2); supporting of commercial land-based recreation (-2); and commercial water-based recreation (-2).

These nine ecosystem services (except land-based hunting) can be found in the -2, -3, or -4 column of at least one of the factor arrays for the environmental perspective, agricultural perspective, and Native American perspective.

Factor B was defined by three participants, two of whom were previously null cases and one of whom was confounding on the environmental perspective and the agricultural perspective (negative loading on the agricultural perspective). The confounding Q-sort for factor B had a loading of 0.7050, which was the highest of the three Q-sorts and, as a result, factor B is in many ways similar to the mirror image of the agricultural perspective (factor 2). For example, the top five ranked ecosystem services for factor B are: Native American cultural and spiritual values (+4); education, management and science (+4); non-Native American cultural and spiritual values (+3); conservation of keystone species (+3); and inspirational and aesthetic values (+3). Inspection of the unimportant side of the agricultural factor array shows Native American cultural and spiritual values (-4); non-Native American cultural and spiritual values (-4); and inspirational and aesthetic values (-3).

The purpose of this brief description of factor A and B is to illustrate that the four viewpoints described above have captured the full range of shared perspectives regarding the importance of water-based ecosystem services despite there being 22 Q-sorts that did not help to define the four viewpoints. The evidence of this is the existence of two factors (A and B) that appear to be alternate manifestations (or a combination) of the four viewpoints (factors 1, 2, 3, and 3A). Factors A and B are defined by 7 and 3 pure Q-sorts, respectively, which leaves a remainder of 12 non-pure Q-sorts. Two of the remaining 12 are confounding cases on factors A and B, and 10 are null cases. The existence of 10 null Q-sorts in the centroid analysis of the remaining 22 Q-sorts supports the assertion that the 14 null Q-sorts in the original solution (factors 1, 2, 3, and 3A) are idiosyncratic viewpoints. In other words, the original three-factor solution captured the full range of shared perspectives regarding the importance of water-based ecosystem services. It is difficult to know exactly why there was a change from 14 null Q-sorts in the original analysis to 10 null Q-sorts in the analysis of the remaining 22 Q-sorts; however, it is most likely due to those Q-sorts that were previously close to a significant loading having a slightly higher loading on factors A or B. For example, Participant 8 originally loaded onto factor 1, 2, and 3 at a value of 0.42, 0.40, 0.41, respectively, which are all just short of the needed value of 0.44 to be considered a significant loading and, therefore, Participant 8 was originally a null case. Participant 8 was not a null case during the analysis of the remaining 22 Q-sorts, but instead she loaded significantly onto factor A at a value of 0.64, which reinforces the investigator's assertion that factor A is a combination of factors 1, 2, and 3.

6.4 Discussion of Factors that Impact the Reception of Most Important Water-Based Ecosystem Services

Objective 4, outlined in Section 1.2, aimed to understand how stakeholders perceived climate change and other factors (e.g. water and land management, water use patterns, population growth, wildfire, invasive species) as a potential threat or an impacting driver to their two most important water-based ecosystem services. This section will be completed in four subsections: (1) discussion of the ecosystem services that were viewed as 'most important' (+4 on the Q-board); (2) presentation of the perceptions of stakeholders with regard to the potential threat of climate change to their most important ecosystem services; (3) explanation of the proportion of the participants that viewed the trends as threatening to their most important ecosystem services; and (4) discussion of other drivers that stakeholders identified as potentially impacting, either positively or negatively, the flow of their two most important water-based ecosystem services.

6.4.1 Ecosystem services that are 'most important'

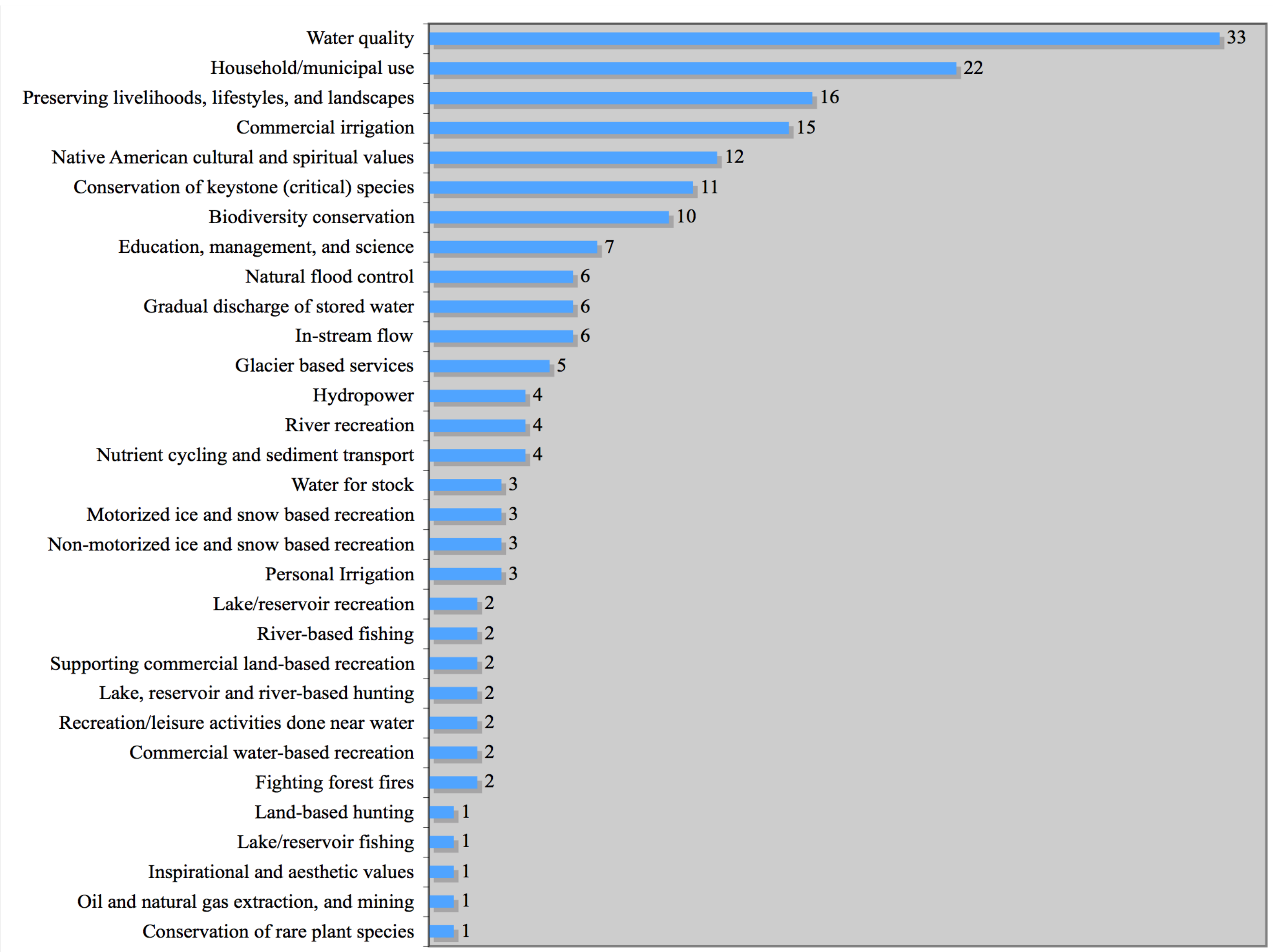
The Q-sorting process required that each of the 96 participants decide their two 'most important' (+4 on the Q-board) water-based ecosystem services, which would be the basis of the discussion about influencing factors. The participants were instructed to sort 34 water-based ecosystem services in order of importance, and 31 out of 34 of those ecosystem services were 'most important' to at least one participant. The three water-based ecosystem services that were not considered 'most important' by any participant were non-native American cultural and spiritual values[18]; manufacturing and industrial use; and physically and mentally challenging recreation. Therefore, these three services will not be discussed in the following discussion on influencing factors.

Figure 6.15 illustrates the descending order of frequency of 'most important' votes for the 31 water-based ecosystem services that were indicated as 'most important' by at least one participant. The water-based ecosystem services that received several acknowledgments

[18] Non-native American cultural and spiritual values were important to the Native American perspective, but it was not "most important."

as the ‘most important’ will be discussed individually with regard to the various drivers that respondents felt were potential threatening to their reception of those services. Those water-based ecosystem services that were ‘most important’ to only a few participants will be discussed in either the context of some specific driver, or in the context of other ecosystem services that have a similar function.

Figure 6.15 Frequency of ‘most important’ votes given by participants



Note: The total of the frequencies presented in Figure 6.15 equals 192, which is the number of participants in the study (96) multiplied by the number of ecosystem services (2) that each participant was required to choose as the ‘most important’ (+4 on the Q-board).

Before moving onto the discussion of factors, it may be beneficial to remind the reader that purposeful sampling was employed in this study, not random sampling. Consequently, care must be taken when extrapolating to the general population those ecosystem services that are viewed as the 'most important', because those views are for this study only. In other words, the participant sample for this study is not representative of the study area population as a whole.

6.4.2 Perceptions related to climate change as a threat to 'most important' water-based ecosystem services

This section will present stakeholders' perspectives of the threat of climate change as it related to their two 'most important' ecosystem services. Those ecosystem services that received ten or more votes as the 'most important' will be discussed individually (see Figure 6.15). In order to understand if stakeholders viewed a changing climate as a threat to their two 'most important' ecosystem services, each participant was presented with four trends that have been attributed to a changing climate. The four trends, as discussed in Section 5.3, are an earlier peak river-runoff, more frost-free days, rapidly melting glaciers, and an increase in average minimum temperatures. Each trend was accompanied by a question as to whether the respondent thought that trend would, "affect your ability to receive your most important ecosystem service."

Table 6.11 illustrates the perceptions of stakeholders related to the threat of climate change for the 31 water-based ecosystem services that were 'most important' to at least one participant. The table highlights the specific ecosystem services that were voted ‘most important’ and the number of participants who perceived each of the four trends as either a threat, not a threat, or were unsure if it were a threat. Each participant was asked to discuss the four climate change trends as they relate to both of their ‘most important’ ecosystem services. Therefore, each trend was discussed 192 times (96 participants each with 2 ‘most important’ ecosystem services).

It is important to make clear that the summary of perspectives reported in Table 6.11 does contain some grey area, because many responses provided by interviewees came with an explanation or a caveat. It was established prior to the questions that there would be no discussion regarding the cause of climate change. Also, even though the trends presented were based on studies that were published in reputable journals, there were some participants that questioned the reliability of those trends. Therefore, there were situations when participants seemed to be appeasing the investigator. For instance, when asked if more frost-free days would impact water quality, Participant 42 suggested, “yes, I think it could if this is a warming trend that is going to continue, and not a cycle.” When asked if rapidly melting glaciers would impact lake/reservoir recreation, Participant 3 replied:

> That certainly would, assuming that. All these questions are geared towards climate change, and being a geologist I do subscribe to the concept of climate change but, yet at the same time, one looks at a broader period of time or a longer period of time than the 80’s till now. Yeah, if we continue to have an increase of 2.6 degrees F per decade, and glaciers diminish to the point that they come extinct then yeah that will certainly

> impact my ability to enjoy lake/reservoir recreation. But ask me that question in 20 years when we are talking about the resurgence of the glaciers, and what are we going to do about the abundance of ice.

Participant 42 and 3 were included in the "threat" category because they were clear that the trends would impact water quality and lake/reservoir recreation, respectively, despite their reservations about the presented trends and the climate change topic in general. There were also participants that were not interested in appeasement. For example, Participant 89 asserted the following with regard to the impact of increasing minimum temperatures on household/municipal use of water:

> I would have to see it over a sustained period of time…I think climate is way [all over the chart], and I don't think man can do anything. My analogy is the one with the little fly sitting on the hub of the chariot saying, 'oh, look what dust I am raising.' I think that is how much man affects climate, I think it is affected by natural causes, it comes and goes.

Participant 89 was included in the "no threat" category because the trends were never fully addressed, other than to say that climate change was not happening. The point to be gleaned here is that the information summarized in Table 6.11 is presented as cut-and-dried. However, there were several instances where responses were more complicated (e.g. "if this" and "but that"), and the investigator had to make decisions within this gray area.

Table 6.11 Perceptions of climate change impacts on the 'most important' water-based ecosystem services

Ecosystem service (Number of stakeholders that voted 'most important' (+4 on Q-board))	Stakeholder perceptions	Trend: Earlier peak river runoff	Trend: More frost-free days	Trend: Glaciers rapidly melting	Trend: Increase in minimum temperatures	Total Votes
Water Quality (33 stakeholders)	Threat	17	12	20	23	72
	No threat	10	14	7	6	37
	Unsure	6	7	6	4	23
Household/ municipal use (22 stakeholders)	Threat	13	12	13	15	53
	No threat	7	8	8	6	29
	Unsure	2	2	1	1	6
Preserving, livelihoods, lifestyles, and landscapes (16 stakeholders)	Threat	10	9	11	12	42
	No threat	6	7	4	4	21
	Unsure	0	0	1	0	1
Commercial irrigation (15 stakeholders)	Threat	8	5	8	6	27
	No threat	7	9	6	8	30
	Unsure	0	1	1	1	3
Native American cultural and spiritual values (12 stakeholders)	Threat	9	9	9	10	37
	No threat	3	3	3	2	11
	Unsure	0	0	0	0	0
Conservation of keystone (critical) species (11 stakeholders)	Threat	10	8	9	9	36
	No threat	1	1	1	1	4
	Unsure	0	2	1	1	2
Biodiversity conservation (10 stakeholders)	Threat	8	8	9	7	32
	No threat	2	2	1	2	7
	Unsure	0	0	0	1	1
Education, management, and science (7 stakeholders)	Threat	6	6	6	6	24
	No threat	1	1	1	1	4
	Unsure	0	0	0	0	0
Natural flood control (6 stakeholders)	Threat	5	4	4	5	18
	No threat	1	2	2	1	6
	Unsure	0	0	0	0	0
Gradual discharge of stored water (6 stakeholders)	Threat	4	5	4	4	17
	No threat	2	1	2	2	7
	Unsure	0	0	0	0	0
In-stream flow (6 stakeholders)	Threat	5	3	5	5	18
	No threat	1	2	1	1	5
	Unsure	0	1	0	0	1
Glacier based services (5 stakeholders)	Threat	5	5	5	5	20
	No threat	0	0	0	0	0
	Unsure	0	0	0	0	0
Hydropower (4 stakeholders)	Threat	1	0	1	2	4
	No threat	2	1	3	1	7
	Unsure	1	3	0	1	5
River recreation (4 stakeholders)	Threat	2	3	2	2	9
	No threat	2	0	1	1	4
	Unsure	0	1	1	1	3
Nutrient cycling and sediment transport (4 stakeholders)	Threat	2	1	2	1	6
	No threat	1	2	1	2	6
	Unsure	1	1	1	1	4

Water for stock (3 stakeholders)	Threat	0	1	2	0	3
	No threat	3	2	1	3	9
	Unsure	0	0	0	0	0
Motorized ice and snow based recreation (3 stakeholders)	Threat	3	3	2	3	11
	No threat	0	0	1	0	1
	Unsure	0	0	0	0	0
Non-motorized ice and snow based recreation (3 stakeholders)	Threat	2	2	2	3	9
	No threat	1	1	1	0	3
	Unsure	0	0	0	0	0
Personal irrigation (3 stakeholders)	Threat	1	2	1	2	6
	No threat	2	1	2	1	6
	Unsure	0	0	0	0	0
Lake/reservoir recreation (2 stakeholders)	Threat	2	2	2	2	8
	No threat	0	0	0	0	0
	Unsure	0	0	0	0	0
River-based fishing (2 stakeholders)	Threat	1	1	1	1	4
	No threat	0	0	0	0	0
	Unsure	1	1	1	1	4
Supporting commercial land based recreation (2 stakeholders)	Threat	0	1	0	1	2
	No threat	2	1	1	1	5
	Unsure	0	0	1	0	1
Lake, reservoir, and river-based hunting (2 stakeholders)	Threat	0	0	0	0	0
	No threat	2	2	2	2	8
	Unsure	0	0	0	0	0
Recreation/leisure activities done near water (2 stakeholders)	Threat	1	1	2	2	6
	No threat	1	1	0	0	2
	Unsure	0	0	0	0	0
Commercial water-based recreation (2 stakeholders)	Threat	1	1	2	1	5
	No threat	0	1	0	1	2
	Unsure	1	0	0	0	1
Fighting forest fires (2 stakeholders)	Threat	2	1	1	1	5
	No threat	0	0	0	0	0
	Unsure	0	1	1	1	3
Land-based hunting (1 stakeholder)	Threat	0	0	1	0	1
	No threat	1	1	0	1	3
	Unsure	0	0	0	0	0
Lake/reservoir fishing (1 stakeholder)	Threat	0	0	0	0	0
	No threat	1	1	1	1	4
	Unsure	0	0	0	0	0
Inspirational and aesthetic values (1 stakeholder)	Threat	1	0	0	0	1
	No threat	0	1	0	0	1
	Unsure	0	0	1	1	2
Oil and natural gas extraction, and mining (1 stakeholder)	Threat	0	0	0	0	0
	No threat	1	1	1	1	4
	Unsure	0	0	0	0	0
Conservation of rare plant species (1 participant)	Threat	1	1	1	1	4
	No threat	0	0	0	0	0
	Unsure	0	0	0	0	0
All 31 ecosystem services that were 'most important' to at least on stakeholder (96 stakeholders with 2 'most important' votes = 192 viewpoints)	Total threat	120	106	125	129	480
	Total no threat	60	66	51	49	226
	Total unsure	12	20	16	14	62
	Total votes	192	192	192	192	768

Overall, stakeholders viewed the trends presented as a threat to water-based ecosystem services derived from the SNF, which is evident by close to two-thirds of possible responses falling into the "threat" category. There were 480 responses out of a possible 768 (96 participants *x* 2 'most important' ecosystem services *x* 4 trends) in the "threat" category, which is nearly 63% of total responses. The sample was mostly opinionated as well, with a limited number of participants that were "unsure" as to whether climate change would impact their two most important water-based ecosystem services.

6.4.2.1 Water quality

33 out of 96 participants (34%) felt that water quality was 'most important'; however, the perceptions regarding climate change and water quality varied. Of the 33 participants that viewed water quality as 'most important', only 4 participants mentioned climate change as a threat to water quality prior to the climate-change prompt, which was given by the interviewer in the form of the follow-up questions.

In response to the four climate-change questions regarding water quality, some respondents felt climate change would negatively impact water quality, and some did not. There were also several situations when the follow-up questions did not yield a quality discussion because the participant was convinced that climate change was not happening and, in some cases, that the trends presented by the investigator were untrue. For example, Participant 6 responded to the four follow-up questions in general, "I do not agree with the studies [presented by the investigator], and you said that we are not going to discuss that and that is fine." The sentiment of Participant 6 indicated that climate change was not a concern because, in their opinion, it was not happening. Therefore, Participant 6 was included in the "no threat" category of Table 6.11.

Table 6.11 shows that more respondents felt that the trends of rapidly melting glaciers, increased minimum temperatures, and earlier runoff were more of a threat to water quality than more frost-free days. The trends of increased minimum temperatures and rapidly melting glaciers were seen as threatening because of the potential impact on water temperature. Participant 13 explained, "glaciers melting is a big deal because it brings up water temp a lot" and, if minimum temperatures increase then, "water temps are up and that affects oxygen and water quality." Participant 63 also made a connection to water temperature affecting quality, "you may have more algae blooms, you may be warming, the water may be warmer, it is just more of setting for the biology to be active, and that is the main problem."

The trend of more frost-free days was the least threatening to the 33 participants that indicated water quality as one of their 'most important' ecosystem services, which may be due to impact that less frost will have on plant growth. Participant 3 suggested, "if we are getting more and more frost free days that might imply that we would have a mature filter strip earlier in the season and perhaps later in the season too. In that regard, perhaps the system can maintain itself and that function [(water quality)]."

6.4.2.2 Household/municipal use

22 out of 96 (23%) felt that household/municipal use was 'most important'. A slightly greater percentage of the participants who felt household/municipal use was 'most important' viewed climate change as a threat than those who acknowledged water quality as paramount, but only one participant mentioned climate change without prompt.

An increase in minimum temperatures was perceived as a slightly greater threat than the other trends, which may stem from a perception that consumption of water would increase. Participant 47 suggested than an increase in minimum temperatures would "affect the amount of water available because our systems can only deliver so much water, and when it is warmer out people use more water. So they put on water restrictions." Also, warmer minimum temperatures could mean, according to Participant 76, that "snowpacks are going to be less and it will be less of a snow driven hydrology," which could decrease the water available for household use.

Participants who did not view the four trends as a threat to household water usually cited the human-made water storage as a safeguard, especially in the case of an earlier peak runoff. Participant 7 noted, "we are going to keep having our water storage, you know the dams, especially the Buffalo Bill dam for our household/municipal water and then the water pipeline infrastructure." Similarly, Participant 18 suggested that an earlier runoff would affect "how they operate Buffalo Bill [dam] and Yellowtail [dam], and Boysen [dam], and it is going to change that, but I think that can be managed to cover [household use]." With regard to the timing of the peak runoff, Participant 25 did not consider it to be a threat to household use because "we have the reservoir." Certain trends presented a not so clear threat to household municipal use. For example, Participant 76 suggested that the rapid melting of glaciers "is going to be enhancing the water supply for a while, and once they are gone it is just going to be a snowmelt driven hydrology; benefit and then, not [a benefit]."

6.4.2.3 Agricultural-based ecosystem services

This section will include the climate change discussion for the four water-based ecosystem services for this project that are directly tied to the agriculture industry: preservation of livelihoods, lifestyles and landscapes; commercial irrigation; personal irrigation; and water for stock. The reason for such an approach is due to the recurrence of certain perspectives for all of the agricultural ecosystem services, and the desire of the investigator to avoid redundancies.

Those participants who consider agricultural based-ecosystem services to be the 'most important' did not generally have climate change on the brain, which is evident by only six unprompted mentions of climate change as an impacting driver to all four agricultural ecosystem services. Those participants who felt agricultural-based ecosystem services were of paramount importance present an interesting viewpoint related to the threat of climate change, because there is potential for a change in climate to have a positive impact. For example, 3 of the 7 respondents who felt that more frost-free days was not a threat to preserving livelihoods, lifestyles and landscapes, went on to say that more frost-free days would be good for the agricultural community. Participant 8 explained, "it could enhance grazing, and it could be good for forage and the grasses. It could increase the growing period, but I am sure that the crops that are currently growing are pretty much in tune with the current climate regime, but maybe we will start growing grapes or something like that."

As discussed in Section 3.4.1.3, greater agricultural production and a shift to high yield crops is exactly what is predicted for high latitude regions (Feng & Hu, 2004). Participant 20 reinforced this point when discussing personal irrigation, "I kind of enjoy more frost free days. I get to grow more garden, more fruit trees. It is actually benefiting me personally, because I can grow more stuff." A similar feeling was evident throughout many of the discussions about the impact of frost-free days on commercial irrigation. Participant 30 suggested, "that could positively affect us…it has been a couple years, but the beet farmers around here…they lost most of their crops because of an early frost." Participant 72 felt that frost-free days could also positively impact water for stock, but for a different reason, "potentially [it] could be beneficial for stock by allowing a longer period of use when the waters wouldn't be frozen."

It is not all beneficial, though, because many participants felt that the loss of glaciers would decrease late season water availability, and the loss of storage would lead to less water overall. Participant 22 asserted, "that is your reserve up on the glacial points [and], as that decreases, then you have less and less reserve. If the temperatures keep getting warmer and warmer as we get through the years, then you have no reserve [and], so, one year can ruin you." Once again, though, the large amount of human-made storage in the study area assuaged many of the concerns about water availability being impacted by climate change. When asked if an earlier runoff would impact commercial irrigation, Participant 31 declared, “Not, because we have dams in place. As long as we can store the water.”

According to some participants, human-made storage may not solve all water-availability issues that will arise with a changing climate. An earlier peak river runoff may require that reservoir managers release water earlier because of a full reservoir, and if the release of water happens too early in the spring, then the agricultural community may not have use for it, resulting in late season water availability issues. Participant 96 explained:

> Buffalo Bill Dam, like last year [2011], had a huge spring runoff, the dam couldn’t hold all the water and yet they had to release a ton of water early in the season when the irrigators didn’t need it, and then later in the season when they did need the water there was still plenty in the dam because it was such a big year. If time of runoff switches and the dam is filling up…again, you are not going to have the water when you need it for agriculture.

An earlier runoff could impact irrigation, according to Participant 45, if it happened rapidly, “we have problems like we did the last couple of years where we had too rapid a runoff and we had flooding. In that case, definitely, it would affect irrigation.”

Similar to water quality and household/municipal use, there were several participants who admitted that the trends presented to them would be detrimental to the agricultural community if they continued, but there was a healthy dose of skepticism that accompanied those admissions. For instance, Participant 72 noted the following about the trend related to rapidly melting glaciers, "In the long term if that is a trend that continues, which I think is a debatable issue, it certainly could have an impact on the quantity of water that is available, particularly late in the season." There were a number of participants who questioned the trend related to rapidly melting glaciers, because there was a feeling that a couple recent cold and snowy winters led to glacial growth. For example, Participant 3 suggested that rapidly melting glaciers would be an issue because "there would potentially be less water in the drainage for agriculture and other uses, [but] I think the last couple winters prior to this winter some of those glaciers grew a little bit." Of the four agricultural ecosystem services, water for stock may be the least vulnerable to climate change in the eyes of the stakeholders, which is evident by the proportion of respondents who felt water for stock was not threatened by climate change being greater than the proportion for all other agricultural based services (shown in Table 6.11). According to Participant 72, an earlier peak river runoff would probably not impact stock as much, "as long as there is some runoff, because you do not need huge amounts for stock water, so you do not need to take advantage of those peak flows necessarily."

6.4.2.4 Native American cultural and spiritual values

12 out of 96 (13%) participants regarded Native American cultural and spiritual values as one of their two 'most important' water-based ecosystem services. As for impacting factors, climate change was not on the forefront of the minds of these particular participants because nobody indicated that climate change was a threat to Native

American cultural and spiritual values without prompt. However, the overwhelming majority of the participants felt that the trends presented would have an impact on Native American cultural and spiritual values.

Mostly, the potential impacts of climate change on Native American cultural and spiritual values pertain to the changes in the timing of natural cycles. The changes in life cycles, or phenology, as a result of climate change are discussed in Section 2.2.3. Participant 64 explained the potential impact of an earlier runoff:

> The riparian areas and things that have been important to the Tribes for hundreds of years, because it is going to change species that are available. Roots, [and] berries might come and go during different time of the year, all of those things I think certainly an earlier runoff would affect that, and it has, there are years that you hear people complaining because there are certain plants they are looking for either came early and froze, or those big changes [impact] that system and it has a negative impact for sure.

Participant 95 also suggested that a change in the timing of runoff could have an impact on Native American spiritual and cultural values:

> A lot of spiritual and ceremonial use of areas, ceremonies are based on natural cycles and, so, if we are changing the natural cycle then the time that that ceremony or that even occurred may then not be matching up what the traditional cycle would be. So, you wouldn't be able to have certain herbs, plants and, then, also for the animals, if part of the ceremonies or the use, Bison hunts [and] things like that.

6.4.2.5 Conservation of keystone (critical) species

11 out of 96 (11%) participants acknowledged the conservation of keystone species as their 'most important' water-based ecosystem service. Climate change was perceived as very threatening to those who felt keystone species were the 'most important', which is evident by 8 out of 11 participants suggesting without prompt that climate change is an issue. The sentiments expressed with regard to the four trends in Table 6.11 suggest, more than any other ecosystem service, that climate change is a threat to the conservation of keystone species.

The climate-change perceptions related to the *conservation of keystone (critical) species* were mostly homogenous and, unlike the perceptions related to other ecosystem services, there were no participants who questioned whether climate change was occurring. Participant 37 was the only participant who valued the conservation of keystone species at +4, and did not think that the trends presented would impact keystone species. Participant 37 felt that the species would adapt, as long as the change did not happen too fast, "I think all these plants and animals in the systems, the water flowing, I think it will all adapt as long as [change] is not fast."

6.4.2.6 Biodiversity conservation

10 out of 96 (10%) participants indicated that biodiversity conservation was one of their two 'most important' ecosystem services. Of the 10 participants who felt biodiversity conservation was of paramount importance, only four mentioned that climate change would have an impact on the ecosystem service without being prompted by the follow-up

questions. Despite the low number that mentioned climate change without prompt, there was a near consensus among the 10 participants with regard to the four climate change trends.

Like keystone species, most participants that felt biodiversity conservation was of paramount importance viewed climate change as a potential threat. However, there was a single unique perspective related to climate change and biodiversity conservation, which was that an earlier peak runoff could "enhance [bio]diversity, particularly if you get peak runoff and more wetland habitat, that always translates to higher diversity in plant and animal species, usually, unless there are other conditions" (Participant 36).

6.4.2.7 Closely related regulating services

The perceptions of climate change as a threat to the following regulating ecosystem services will be discussed in this subsection: natural flood control, gradual discharge of stored water, glacier-based services, in-stream flow, and nutrient cycling and sediment transport. These ecosystem services are discussed together because the ecosystem functions that provide them are closely entwined. For example, glaciers in the study area facilitate, among other things (e.g. healthy forests), the gradual discharge of stored water throughout the summer months. Also, adequate in-stream flow will ensure that nutrient cycling and sediment transport is taking place, and it will maintain healthy riparian habitats that will promote natural flood control.

Climate change was considered threatening to these regulating ecosystem services by most of the participants who felt they were of paramount importance. The only exception was nutrient cycling and sediment transport, which was not considered to be threatened by climate change by the majority of participants who regarded it as the 'most important'. Most respondents did not mention without prompt that climate change was going to influence their ability to receive natural flood control, gradual discharge of stored water, in-stream flow, and nutrient cycling and sediment transport. However, 4 out of 5 participants who considered glacier based services to be one of their 'most important' water-based ecosystem services mentioned climate change as an impacting factor prior to the follow-up questions.

In addition to the threat of the four trends to the aforementioned regulating services, there was concern that an increase in the magnitude of precipitation events could impact natural flood control. Participant 2 suggested, "they are calling for more intense short duration storms, which could have an impact on the ability of attenuation of water." One participant indicated that the amount of rain would have an impact on the gradual discharge of stored water. Participant 9 asked rhetorically, "how much rain are we getting to drive the melt and the timing [of the melt]?" According to Participant 69, the gradual discharge of stored water will also be impacted by the loss of glaciers, and more precipitation events coming in the form of rain instead of snow. Participant 69 noted, "The earlier runoff means that you are having a warming spring, which means that you are getting less snow and more rain which means that everything is going to start coming out faster including those glaciers that provide the late season flow."

6.4.2.8 Hydropower; oil and natural gas extraction, and mining; and fighting forest fires

Overall, climate change was not seen as a threat to hydropower or oil and natural gas extraction, and mining. The most threatening trend to hydropower was an increase in average minimum temperatures, which was seen as potentially impacting snowpack. Participant 43 suggested that an increase in minimum temperatures "would affect hydropower, because if your snowpack melted earlier it might have an affect on how you stored water or how much [water was stored] and, it may, you may have to alter your operations." There was also uncertainty regarding the impact of certain trends to hydropower. For example, 3 out of the 4 participants who indicated hydropower was one of their 'most important' ecosystem services stated that they were unsure if more frost-free days would have an impact on hydropower. Of the two participants who felt fighting forest fires was 'most important', one considered climate change to be a threat to the ecosystem services, but they did not elaborate as to why.

6.4.2.9 The remaining water-based ecosystem services

Up to this point, 17 of 31 water-based ecosystem services that were 'most important' to at least one participant have been discussed with regard to stakeholder perception's about the threat of climate change. The 14 ecosystem services that have not been discussed in relation to the threat of climate change are cultural services, with the exception of the conservation of rare plant species, and 11 of those ecosystem services are related to recreation.

As shown in Table 6.11, the majority of the remaining 14 water-based ecosystem services are considered, by stakeholders, to be threatened by a changing climate. However, there were only 4 mentions of climate change that came without prompt, and two of those were in relation to non-motorized ice and snow based recreation. Similar to many of the other ecosystem services, there were several times when the participants admitted that climate change would impact their 'most important' services if it continued to happen, but there was some skepticism regarding that topic. For example, Participant 56 remarked the following as it related to motorized ice and snow-based recreation, "as far as climate change, if what they are predicting really pans out and we get warmer and drier that could definitely have an effect because we would have less snow later in the year in a shorter amount time…I don't think it is as predictable as people say, so I do not know if it is going to get warmer and drier like they say."

One participant was concerned that river recreation would be impacted by an earlier runoff because the timing of optimum flows would not coincide with the timing of optimum weather. Participant 75 explained, "You know, [an earlier runoff is] pushing things earlier, so it is colder. An earlier runoff would, and then you have a longer extended warm part of the season where [the water] is lower. So the more enjoyable climate atmosphere would not be there." The rapid melting of glaciers was also a concern for Participant 75 as it relates to river recreation, "particularly in the low water years, it is basically just a water bank is what glaciers end up being and [they] help to contribute during those years."

The loss of glaciers, if they are in fact melting, are also concerning for the one participant who considered land-based hunting to be ‘most important.’ Participant 28 stated, “It could affect my hunting probably, just by where the animals would be…having those glaciers runoff making the grass green up there makes it easy to hunt, because they have green grass to eat and that is where they would like to be. So [not having that runoff] would definitely impact that but, like I said, from 2005 we have probably been building glaciers.”

6.4.3 Proportion of participants that viewed the trends as threatening

Table 6.11 and the subsequent discussion described how the four climate change trends were perceived as potential threats to the ‘most important’ water-based ecosystem services, but it does little to summarize the climate-change perceptions of the 96 participants as a whole. For example, there were 480 responses out of a possible 768 (96 participants *x* 2 ‘most important’ ecosystem services *x* 4 trends), which indicated that participants viewed the four trends as a threat to the 31 ‘most important’ water-based ecosystem services. The 480 responses are nearly 63% of total possible responses, but given that the responses were aggregated by ecosystem service and not by respondent, Table 6.11 is not helpful in identifying the proportion of the participants who felt threatened by the trends.

In order to gain a better understanding of how the participants as a whole viewed climate change as a potential threat to important ecosystem services, Table 6.12 illustrates the number of participants who perceived at least one of the four trends as threatening to at least one of their 'most important' ecosystem services. The Table is divided by viewpoint (e.g. agricultural perspective), and it also presents the perceptions of those participants who did not help to define any of the four viewpoints. Table 6.12 includes a category for those participants who felt threatened by at least one of the climate change trends, but were skeptical of climate change being anthropocentric. Table 6.12 highlights the number of participants who did not believe that the four trends were a threat to either of their two 'most important' ecosystem services (row for "number of participants not threatened"). The Table also includes a category for those participants who were dismissive of climate change, which resulted in them being included in the group of participants who felt they were not threatened by the climate change trends.

Table 6.12 Perceptions of the threat of climate change by factor

Perceptions related to climate change	**Viewpoints related to water-based ecosystem services**					
	Environmental perspective	Agricultural perspective	Native American perspective	Recreation perspective	Non-viewpoint defining participants	Total participants
Total Participants	35	26	8	5	22	96
Number of participants threatened	32	21	6	5	21	85
Number threatened, but skeptical	4	8	0	2	2	16
Number of participants not threatened	3	5	2	0	1	11
Number not threatened, and dismissive	2	1	0	0	0	3

To clarify which participants were included in the row for *number threatened, but skeptical* it is important to reiterate a discussion from Section 5.3. The investigator made it clear to the participants during the survey that part of the project was interested in understanding if stakeholders perceived climate change as a potential threat to their two ‘most important’ ecosystem services, but there would be no discussion about the topic of the cause of climate change. Most participants did not broach the topic regarding the cause of climate change, but there were a number of participants who were unwilling to admit that the climate change trends presented to them were a threat to their ‘most important’ ecosystem services without adding that they believed climate change was nothing more than a natural cycle and, therefore, not human caused.

There were also a few participants who were dismissive of climate change, which resulted in them being placed in the category for *Number not threatened, and dismissive*. For example, when prompted with the four climate change trends by the investigator, Participant 21 replied with the following:

> I am sure that you believe in global warming but, for me, not so much. I realize that there is an impact from pollution and those kinds of things, but I think our universe changes anyway, and there is nothing that we can do about it. It is just going to happen, and if you look back over water history in the last 150 years when it has been recorded, you will see that a lot of the same scenarios have played themselves out over and over.

It was clear to the investigator that Participant 21 was not interested in discussing climate change trends but, just to make sure, the investigator asked, “so, you do not see these changes as a threat to either of [your two ‘most important’ ecosystem services]”, to which Participant 21 replied, “No, I don’t”.

The percentage of participants who viewed at least one of the trends as a threat to at least one of their two 'most important' ecosystem services was 88.5% (85 of 96 participants). Those participants are included in the *number of participants threatened* category and, therefore, it can be inferred that climate change is a threat to their 'most important' ecosystem services. The investigator is comfortable making such an inference because it is a changing climate that has led to the four trends presented to the participants during the follow-up discussion, and to be threatened by one trend is to be threatened by a changing climate in general. However, stating that the 85 participants who felt at least one of the four trends was a potential threat to their 'most important' ecosystem services are participants who feel threatened by climate change could be a misrepresentation of stakeholders' perspectives.

In order to avoid such a misrepresentation, Table 6.12 includes a category for those participants who were skeptical. Of the 85 participants who were threatened by the four trends, 16 (19%) explicitly expressed skepticism that the trends presented were anything more than a natural cycle, thereby, disagreeing, at least in part, with the notion of anthropocentric climate change. For example, Participant 15 stated:

> On a [short] time scale versus a long scale we are not sure, there are a lot of things on climate change that has people skeptical. I have been working very closely on a climate change study…I am aware of all these [four trends]. Do I believe it all? No. I am still skeptical that it may just be a blip, but it doesn't mean that I do not think we need to do something with greenhouse gases.

Due to the skepticism of the 16 participants, it is important to clarify that even though 88.5% of participants are threatened by the trends, only up to 72%[19] (85 threatened participants minus 16 skeptical participants = 69 participants/96 total participants = 72%) of participants can be considered as being threatened by climate change. However, it can be asserted that the remaining 28% of participants (the 27 participants not considered to be threatened by climate change) are not, from their perspective, threatened by anthropogenic climate change. The participants who were defined as skeptical in this project can be compared to the Doubtful population defined by Maibach et al. (2009), which was discussed in Section 2.2.1. The skeptical participants were similar to the Doubtful group in that they were "more likely to say that global warming is caused by natural changes in the environment" (Maibach et al., 2009, p. 61).

There were 11 participants who did not consider the four trends to be threatening to their two 'most important' ecosystem services, which would indicate that those participants are not concerned about the trends that climate change is inducing. Three of those participants are categorized as dismissive, which means they were unwilling to have a discussion about climate change because, in their mind, it is not happening. The dismissive participants for this project conveyed attitudes similar to some of those held by the Dismissive group defined in the six Americas work by Maibach et al. (2009). Two of those prevalent attitudes were that climate change is not threatening and not happening.

[19] The use of the phrase "up to 72%" suggests the possibility that there are other skeptical participants within the 69 whom are being considered threatened by climate change because, by not expressing skepticism, the participants were following the instructions of the investigator to not discuss the cause of climate change.

Using Table 6.12, it is possible to better understand how each of the viewpoints perceives a changing climate with regard to the 'most important' ecosystem services. The majority of participants who make up each viewpoint, including those participants who did not load onto any factor, see climate change as a threat to their 'most important' water-based ecosystem services. However, the viewpoints with the most skeptical participants were the recreation perspective (2 out of 5 participants (40%)) and the agricultural perspective (8 of the 21 participants (38%)). The viewpoint that had the most dismissive participants was the environmental perspective.

6.4.4 Other factors that stakeholders view as potentially impacting their 'most important' water-based ecosystem services

Prior to introducing the follow-up questions that were targeting stakeholders' perspectives related to climate change, they were asked by the investigator, "what factors, influences, or things to do you see as potentially affecting your ability to receive your two 'most important' water-based ecosystem services in the future, either positively or negatively?" There were a diverse range of factors identified by participants, and this section will present those factors. Similar to the previous section, several of the more popular ecosystem services will be discussed individually, and those ecosystem services that were 'most important' to only a few people will be discussed generally with regard to potentially impacting factors.

6.4.4.1 Water quality and household/municipal use

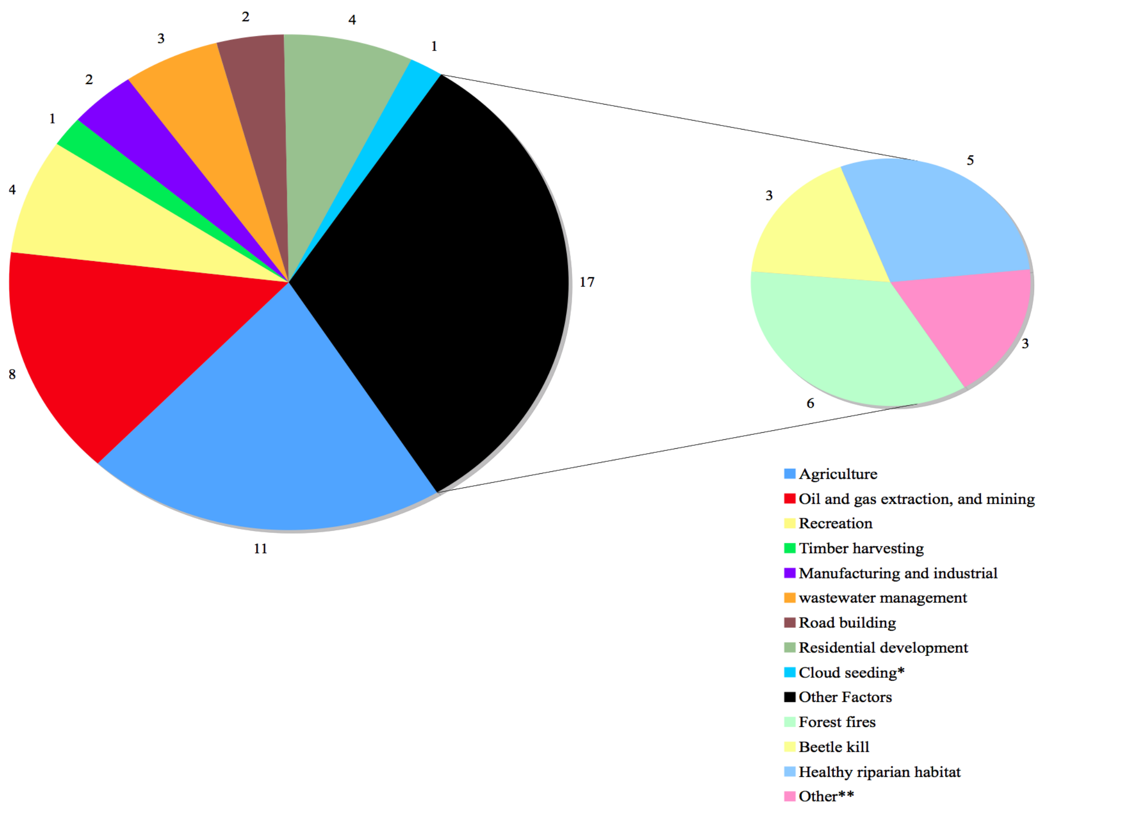
Apart from climate change, there were several factors that participants indicated would impact their ability to receive high quality water. Figure 6.16 illustrates the factors that stakeholders felt would impact water quality. Figure 6.16 is mostly composed of factors that are within human control (e.g. *agriculture* and *timber harvesting*), but about a third of the pie chart is composed of *other factors*, which are those factors that are mostly related to natural forces (e.g. *forest fires* and *beetle kill*). The investigator acknowledges that forest fires may be started by humans, however, it is a force that is mostly out of human control.

All factors were seen as drivers that would negatively impact water quality, with the exception of *healthy riparian habitats*, which was seen as a factor that would maintain high quality water. The values in Figure 6.16 reflect how many participants mentioned each respective driver and, as shown, agriculture and oil and gas extraction, and mining compose about a third of the responses related to those drivers that could impact water quality. According to one participant the SNF is experimenting with *cloud seeding*, which is seen as an activity that could negatively impact water quality. Participant 58 explained:

> We did explain it to the State of Wyoming, that you are causing problems with this cloud seeding. Plus they did not get permission from the Tribes to do it, and they are doing it on the borders of the [Wind River Indian] Reservation, so, they are affecting our water, our water quality.

The concern related to the cloud seeding has to do with the fall out of chemicals that are used during the process. Participant 58 specifically mentioned silver nitrate as the chemical of concern.

Figure 6.16 Factors influencing water quality



Notes: *Cloud seeding, according to Davies (2009), is a weather modification technique that "involves injecting clouds with chemicals that encourage water vapor to form ice crystals heavy enough to fall, melting on their way to produce rain."

**Other factors included population, erosion, and drought.

The other drivers that participants viewed as potentially impacting household/municipal use were water quality and water availability. The biggest concern for participants who felt household use was the 'most important' was the quality of water, which can be impacted by all of the drivers mentioned above. However, specifically for household use, there was a concern that groundwater contamination could happen from hydro-fracking, or other pollution that originates in the air. Participant 47 suggested that oil and gas fields pollute the air, which ends up in the high mountain rivers via acid rain and, as a result, negatively impacts the water used for drinking.

The second largest concern related to household/municipal water is the state of water-related infrastructure, such as water mainlines and lagoons. Participant 53 stated, "the only real threat that comes to mind is the robustness of our municipal water system. It is not unusual for a main [pipe] to break, and then you do not know if you are going to have water." Participant 78 conveyed a concern held by many of the residents living in Crow Agency, MT:

> We are probably the only community besides Hardin that, on the Reservation, uses surface water for its municipal water…so the quality of the rivers is critical to our drinking water. This past summer when we had that flood, there was near panic level because of what was in the river already, and then the Lodgegrass Lagoon got washed out and, so, that was headed downstream fast too. So, for three days our water plant was shut down.

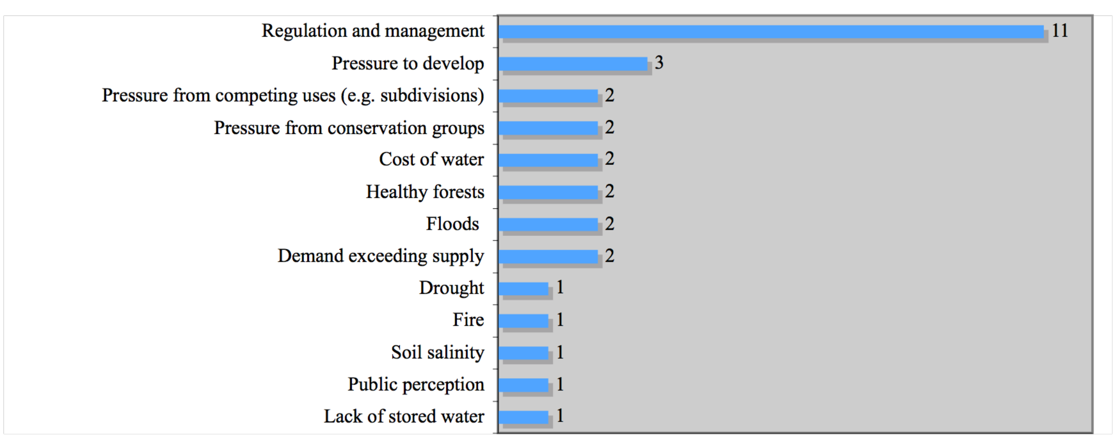
Other concerns related to the reception of household/municipal water are development of subdivisions, which could stress water further. The loss of glaciers and inadequate stream flow were also mentioned as potentially having a negative impact on household/municipal use.

6.4.4.2 Agricultural-based ecosystem services

There were several factors that participants felt would impact their ability to receive the agricultural-based ecosystem services. A greater concern than climate change, perhaps, were regulations and management of the use of water for agriculture. Regulation and management was by far the factor cited the most and, according to Participant 4, "we are not against regulation by any means, but if there is no balance then other interests tend to take the forefront…if it goes unchecked then down the road you end up with so many regulations that you cannot afford to keep farming." Participant 72 was concerned about grazing permits on the Forest: "Obviously a lot of that water is used for stock up on the forest, so the ability to maintain lifestyle gazing permits on the forest would be on of the most critical ones to be able to make that use."

Regulation and management were mentioned eleven times by participants as a factor that impacts their agricultural water-based ecosystem services. Figure 6.17 outlines the other factors that were mentioned as potential impacts to agricultural ecosystem services.

Figure 6.17 Factors impacting the reception of agricultural ecosystem services



Other than regulation and management, Figure 6.17 highlights a variety of other factors that participants see as potentially impacting their ability to receive agricultural water-based ecosystem services. The potential impact of each factor is mostly obvious (e.g. the impact of flooding on agriculture), but there are a few factors that need explanation. The pressure to develop refers to the possibility that large plots of agricultural land could be developed into residential subdivisions, a point which motivated the inclusion of the preservation of livelihoods, lifestyles, and landscapes as an ecosystem service for this project. Two respondents indicated that healthy forests are important for the agricultural community. Participant 35 asserted, "if we were to lose significant amounts of forest cover over large areas we would become, the streams themselves would become, a term called 'flashy', where they flood or they don't run, and nothing in between. That is a huge deal for all aspects that, we as a community, are dependent on, and those of us who are in agriculture."

Participant 71 suggested that public perception could impact the agricultural community:

> Public perception would be a huge thing if people do not understand agriculture and the culture that it brings, the lifestyle that it brings, how it influences landscapes. So public perception is probably the biggest thing, and that leads to a whole suite of other things. Different groups, if you see things different you might litigate, or you might disagree with the ag kind of lifestyle.

The importance of the *culture* of agriculture within the study area that is being stressed by Participant 71 was discussed in Section 3.3, and if the public perception shifts to viewpoint that sees agriculture as less important then the community may be impacted.

6.4.4.3 Native American cultural and spiritual values

Other factors not related to climate change that respondents felt would impact Native American cultural and spiritual values are: water quality, water quantity, access, land use, lack of understanding by non-Native populations, management, and lack of respect. Water quality, which is crucial for ceremonies like the "Sacred Sweat", was the most mentioned factor that could potentially harm the reception of Native American cultural and spiritual values. Water quantity, or in-stream flow are important for maintaining healthy riparian habitats that support sacred plants. Access to cultural sites and expansion of land use were also factors that could potentially impact the reception of Native American cultural and spiritual values. Participant 52 explained,

> Cultural values will be impacted by denying access to the resource on the forest, and by allowing activities without due consideration for the resource. Especially special roots, trees, and herbs that are important. Access and other activities can affect the utilization of very important spiritual and protective aspects of the plants and resources on the forest.

Similarly, Participant 63 remarked, "any activity or access would be to some of the areas that were traditionally used, they have a specific meaning to certain groups. Either access or use of that area, and destroying it."

A lack of respect for the resource was also cited as a potential impact to Native American cultural and spiritual values. A “lack of respect”, cited by Participant 48, seemed to allude to development: “Just people not respecting it basically. The use of it, and it kind of goes back to water quality. If we were to build a ski resort up there, or houses up there, build something next to the river or inside the river to damage the watershed.” Participant 82 stated without elaboration, “we were taught to respect the water.”

Participant 58 suggested that Native American cultural and spiritual values could be impacted by a lack of understanding by non-Native populations:

> I think that is one of the things that the white culture don’t really take into account. Most of the theories and all of the conclusions they come to is scientific, but they never look at the cultural part of the traditional peoples. It is one of the reasons that water is very important. Water is very important to the people, it is one of the main life giving resources that is on the Reservation, throughout the whole world, if it wasn’t for water we would not be existing… everything has got a spirit, according to the tribal people, everything has got a spirit. The rocks you stand on, the soil you stand on, the water you drink, the air you breath, the sun, the moon, the owls, the wildlife, even the air that you breath, it has got a spiritual value in it. It is one of the things that the majority of people don’t see, is that the spirit isn’t a God. It isn’t like in some societies you put a God to different things, like this is a water god, that’s a soil god, that is just a god god, you know? Ours is just, all within, together, it is all within one society, and it

> makes up one society, and all of these little beings and little plants, and all these rocks, and the water is all together. We are all one community, and once you start destroying parts of it, you are destroying yourself.

The differences in culture between Native American populations and non-Native American populations may create a barrier of understanding, where non-Native populations cannot truly grasp the importance that Native populations assign to water.

6.4.4.4 Conservation of keystone species and biodiversity conservation

Other factors that were perceived as potentially impacting keystone species were management, water quality, water quantity, drought, development of national forest land for oil and natural gas extraction, cloud seeding, and over use for recreation (i.e. OHVs). There was not a single factor, other than climate change, that was mentioned more than twice by the 11 participants who valued the conservation of keystone (critical) species as 'most important'. The topic of cloud seeding was raised in relation to the conservation of keystone species but, unlike water quality, it was seen as a potentially positive driver. Participant 55 explained:

> If the trend is less snowpack, and if the cloud seeding does appear to work [it could] be a beneficial thing to some of these higher elevation species that we are thinking of, like whitebark pine and so on. Just increasing snowpack and that sort of thing, not only for keystone species, but for water delivery later in the summer for irrigators and municipal water supply.

The positive impact that cloud seeding could have on keystone species, irrigation, and municipal water is accompanied by an uncertainty regarding potential side effects. Participant 55 remarked:

> There has been a pilot study, I think, around the last four or five years, where these machines, I do not know how much of a pollutant it is, I do not know a lot about it, but they pump silver ions of some sort into the atmosphere and they are used as the nuclei that these particulates are in the atmosphere and that is what clouds need in order to coalesce to that nuclei and then eventually it creates a snowflake.

Participant 58 seemed more pessimistic about cloud seeding, and felt that it could negatively impact fish populations, "I think it is the silver nitrate that they use that has a major effect on the plankton that is in the high river, high lake, mountain lakes, and most of the fish up there they eat this plankton, and that silver nitrate is killing off the plankton which means the fish don't have anything to eat."

Many of the same non-climate change related factors were mentioned for biodiversity that were mentioned for keystone species (i.e. development, drought, and management). Additionally, several participants felt that the mountain pine beetle will impact biodiversity and, at the same time, those participants acknowledged that climate change would make the mountain pine beetle outbreak worse. Participant 96 explained, "an increase in average minimum temperature leads to an increase in mountain pine beetle, which leads to a loss of whitebark pine, which has all sorts of implications for biodiversity."

6.4.4.5 Closely related regulating services

This subsection will discuss factors, other than climate change, that impacted the following regulating services: natural flood control, gradual discharge of stored water, in-stream flow, glacier-based services, and nutrient cycling and sediment transport. These services are discussed together for the same reasons that they were discussed together with regard to climate change (Section 6.4.2.7). The factors most commonly cited with regard to these regulating services were agriculture and healthy forests and vegetation.

Agriculture was considered to be a potential negative driver to in-stream by 4 out of the 6 participants who felt it was 'most important'. Participant 60 asserted, "the use in particular that is a tremendous challenge to in-stream flow is irrigation, and diversion." One participant considered agriculture to be potentially beneficial to the gradual discharge of stored water. Participant 39 suggested that, "natural storage is enhanced by flood irrigation because you pull it out and it sticks in the banks."

Healthy forests and vegetation were considered to be positive factors for the gradual discharge of stored water and natural flood control. Participant 35 explained that, "when you think about how a forest should work, ideally having multiple species of trees and multiple ages of trees. Those are the factors that I think will help us." Participant 35 went onto assert that the SNF is in trouble because it's forests are dying and are composed of trees that are of the same age and, therefore, it is more vulnerable to being decimated by forest fires, which would result in “flashy streams” and a less gradual discharge of stored water.

6.4.4.6 Hydropower; oil and natural gas extraction, and mining; and fighting forest fires

The only factor that was discussed, other than climate change, in relation to hydropower was snowpack. The magnitude of the yearly snowpack was mentioned by 2 of the 4 participants that felt hydropower was ‘most important’. Participant 43 stated, “It would be based strictly on snowpack, in years where there have been low snowpack we have no been able to generate as much power. In years where there is a good snowpack, above average, and record levels, we have been able to generate and provide that benefit to the public.” There were no specific drivers mentioned for oil and natural gas extraction, and mining or the fighting of forest fires.

6.4.4.7 The remaining water-based ecosystem services

Up to this point, 17 of the 31 ecosystem services that were ‘most important’ to at least one participant have been discussed with regard to the factors or influences that participants felt would impact their ability to receive those services. The remaining 14 ecosystem services will be discussed by driver, because there are several ecosystem services that had only one or two drivers mentioned and were ‘most important’ to only one or two participants. Also, with the exception of the conservation or rare plant species (a regulating service that was ‘most important’ to one participant, who did not mention any drivers), the remaining fourteen ecosystem services are cultural services, and most of them are related to recreation.

Water quality was mentioned several times as an influencing factor for cultural water-based ecosystems such as river-based fishing; river recreation; inspirational and aesthetic values; and non-motorized ice and snow-based recreation. Management was also a factor that participants considered to be influential to their ability to received water-based ecosystem services such as motorized ice and snow based recreation, lake/reservoir based recreation, and inspirational and aesthetic values. Participant 79 suggested the following with regard to inspirational and aesthetic values, "improper management, people not using best management practices and kind of degrading stream sides and that sort of thing."

The only driver, other than water quality and management, which was mentioned more than once was forest fires, which was seen as a threat to lake/reservoir based recreation and river recreation. Participant 3 asserted that lake/reservoir based recreation is impacted by "all the debris that comes down and fills reservoirs. I am a sailor and, so, I do sailing and sailboarding out on Buffalo Bill [Reservoir]. My season is impacted by debris floating down, like after the Gunbarrel fire." Participant 11 suggested that forest fires are an issue for river recreation, because the "chocolate water" creates an experience that is not as enjoyable as it would be if the water were clear.

Overuse of the resource was mentioned as a limiting factor for commercial water-based recreation and river recreation, but for different reasons. For commercial water-based recreation, Participant 64 was concerned with over allocation of the water in the river, "The over commitment of the river [would negatively impact commercial water-based recreation], so less water being stored in Boysen [Reservoir]." For river recreation, Participant 26 remarked that overuse of the river corridor can impact the its inhabitants, "kayaking, canoeing, a lot of those raft companies, and things the people bring debris down the river which creates pollution. Such as flipflops, life vests that are not recovered, things like that, which birds and other animals get tangled up in."

According to Participant 80, commercial water-based recreation can also be negatively impacted by management, which may focus on other water-based ecosystem services like hydropower. Participant 80 suggested, "so if anything comes up with any kind of, if it is hydroelectric power, anything with commercial fishing, or irrigation those are going to prohibit a lot of things that I enjoy doing for rafting, kayaking, fishing, and that kind of thing."

The last drivers to be discussed are related to education, management, and science, which is an appropriate ending to this discussion because, in the end, this project is interested in improving management of water resources that impact a wide range of stakeholders. Seven participants indicated that education, management, and science was one of their two 'most important' ecosystem services, and the drivers that were seen as impacting that service were funding, and management. Participant 17 suggested that a loss in funding for education, management and science would have a negative impact, "the first thing that comes to mind is funding, with the economy the way it is and the budget at the national level and all the way down the way it is, I guess that I am worried that there will not be funds devoted to research and I think there be."

The second driver mentioned was management, which is related to the comment on funding. Participant 42 remarked:

> Well, I think our managers, whether they are with the State or the Federal United States Fish and Wildlife Services, need to come on board with up-to-date management practices, not things that are 50 years old, 'like lets just throw more fish in there if we have a problem.' They need to study it, they need to manage it and they need to make decisions based within the system, not because somebody wants to catch 6 fish or take 12 bull elk.

These two factors related to education, management, and science highlight the overall struggle that is inherent in making water management decisions. There is a push from stakeholders to make management decisions that are relevant to the locale in question, and to make those decisions within the context of the current day issues without getting caught in the quagmire of old management plans. At the same time, funding is necessary to complete projects, like this one, which are aimed at improving the available information that is used for making land and water-management decisions.

6.5 Summary

This chapter presented the results of the Q-set, P-set, analysis of 96 Q-sorts, and the discussion of drivers. The Q-set was composed of 34 water-based ecosystem services, which were then considered by the 96 participants that composed the P-set. The considerations of the 96 stakeholders were presented via the Q-sorts, which were then factor analyzed using the centroid method to yield four distinct viewpoints (i.e.

environmental perspective, agricultural perspective, Native American perspective, and recreation perspective) regarding the importance of water-based ecosystem services derived from the SNF. Each of the 96 participants were required to decide their two most important ecosystem services, which were the ecosystem services that were the focus of the drivers discussion. Every stakeholder was given the opportunity to voice their opinion about any factor or influence that they felt would impact the flow of their two 'most important' water-based ecosystem services. However, the primary focus of the drivers discussion was to understand the perceptions of stakeholders as they relate to the threat of a changing climate on their two 'most important' ecosystem services.

The results of the drivers discussion showed that about two-thirds of respondents considered a changing climate to be a threat to their two 'most important' water-based ecosystem services, however, these results must be approached with caution because of the varying beliefs about the cause and reality of a changing climate. There was a wide range of factors or influences that were not related to climate change, but high quality water was perhaps the driver most commonly discussed because, without it, many of the other water-based ecosystem services are negatively impacted.

Chapter 7

Discussion of Factors and Recommendations of Water-Based Ecosystem Services to be considered in Phase II of Research

The chapter will compare and contrast the four distinct viewpoints regarding the importance of water-based ecosystem services derived from the Shoshone National Forest (SNF). A firm understanding of the differences and similarities between the four viewpoints is vital, because the information gathered for this project is the foundation of a larger project. Ultimately, the larger project will create a decision-support tool for land managers, who are tasked with the difficult challenge of overseeing the use of public water resources that supply a wide range of benefits, many of which are competing, to a gamut of interested parties. Therefore, when making recommendations for the ecosystem services to be carried forth to future phases of research, it is important to consider the types of tradeoffs that land managers may be confronted with as those who align with the environmental perspective, agricultural perspective, Native American perspective, and recreation perspective pursue the water benefits that are integral in their lives. So, this chapter will proceed in two parts: (1) a discussion of the three factors (four viewpoints) that resulted from centroid factor analysis of the 96 Q-sorts; and (2) recommendation of several water-based ecosystem services to be valued using both non-market and market valuation techniques during a future phase of research.

7.1 Discussion of Factors

The three factors that resulted from data analysis yielded four distinct viewpoints, which were interpreted and articulated in Section 6.3.3. The interpretive write-ups presented for each viewpoint in Section 6.3.3 inherently created comparisons between the viewpoints, however, this section aims to further those comparisons by highlighting specific ecosystem services that are in consensus or in disagreement among the four viewpoints.

An output of PQMethod, not yet discussed in the context of this project, can help to further clarify the similarities and differences between factors. Table 7.1 illustrates the correlations between factor scores for the four viewpoints. A certain amount of correlation between factor scores is inevitable, but the correlations do not mean that rotation was not orthogonal, which is a point that is discussed in Section 4.2.5.6.

Table 7.1 Correlations between factor scores

Perspective	Environmental	Agricultural	Native American	Recreation
Environmental	1.0000	0.0868	0.3733	-0.1034
Agricultural	0.0868	1.0000	0.2140	0.3318
Native American	0.3733	0.2140	1.0000	-0.4986
Recreation	-0.1034	0.3318	-0.4986	1.0000

As shown in Table 7.1, the recreation perspective and the Native American perspective, which are opposing viewpoints on a bipolar factor, have a correlation between factor scores of -0.4986. The reason for this value is mostly because of the opposite level of importance assigned to several cultural services (those in green in the factor-array figures in Section 6.3.3) by each of the viewpoints. If the investigator had used the mirror image approach for interpreting the bipolar factor (third factor), then the correlation between factor scores for the Native American viewpoint and the recreation enthusiast viewpoint would have been -1.0000. By not using the mirror image approach, the investigator was able to interpret the two viewpoints in a more nuanced fashion and find agreement or disagreement between the two viewpoints that otherwise would have been lost. For example, the mirror image approach would have had the ecosystem service entitled household/municipal use valued at +1 for the Native American perspective and -1 for the recreation perspective. As can be seen in Figure 6.13, the Native American viewpoint ranked household/municipal use as +3. Figure 6.14 showed that the recreation perspective ranked household/municipal use as +4. The point to be gleaned from this discussion is that even though the two viewpoints (Native American and recreation) are highly negatively correlated, there are still certain ecosystem services that both viewpoints ranked similarly.

Table 7.1 indicates the viewpoints that may have certain common (or opposing) themes. For instance, the environmental perspective and the Native American perspective have a correlation between factor scores of 0.3733, which indicates some commonality. The relatively high value of the correlation between factor scores can be, at least in part, attributed to the preference given to the regulating services by both the Native American viewpoint and the environmental viewpoint. In fact, both viewpoints ranked all regulating services at 0 or above. The correlation between factor scores for the agricultural perspective and the recreation perspective is 0.3318, which is partly due to their agreement on the importance of river-based fishing (+2 for the agricultural advocate and +4 for the recreation enthusiast), and preserving livelihoods, lifestyles, and landscapes (+3 for the agricultural advocate and +2 for the recreation enthusiast). Also, the two viewpoints assigned the same unimportance to non-native cultural and spiritual values (-4 for both), conservation of rare plant species (-2), and biodiversity conservation (-1). The correlation between factor scores of 0.2140 for the agricultural perspective and the Native American perspective is partly due to the similar level of importance assigned to water quality (+4 for the Native American viewpoint and +3 for the agricultural viewpoint), hydropower (+2 for both), and water for stock (+2 for the Native American viewpoint and +3 for the agricultural viewpoint). The two viewpoints also agreed on the unimportance of manufacturing and industrial use of water (-1 for both).

By investigating the likely reasons for the values in Table 7.1, it becomes evident that the environmental perspective favors the less tangible ecosystem services (e.g. nutrient cycling and sediment transport), which are classified as indirect-use values when using the classification framework by value discussed in Section 2.1.2. The agricultural perspective, which has little in common with the environmental perspective (0.0868 correlation between factor scores), favors those ecosystem services that are tangible products (e.g. commercial irrigation), and are classified as direct-use values. The recreation perspective also prefers the direct-use values, although they generally prefer cultural ecosystem services (e.g. river-based fishing) as opposed to the production services (e.g. water for stock) favored by the agricultural perspective. Finally, the Native American perspective prefers a mix of tangible direct-use values (e.g. hydropower), less tangible direct-use values (e.g. Native American cultural and spiritual values), and non-use values (e.g. non-Native American cultural and spiritual values). The non-use value attributed to non-Native American cultural and spiritual values can be further classified as an altruistic value, which is the utility derived from knowing somebody else benefits from the ecosystem service.

Finding consensus among the four viewpoints may be important, which is evident by PQMethod's output that outlines the "consensus statements" (discussed in Section 4.2.5.6). However, for this project there were no statements that were in total consensus, which means that each statement had at least one viewpoint that ranked the statement differently enough from the other three viewpoints to be deemed statistically distinguishable. Despite the lack of statements that were in statistical consensus, there were two water-based ecosystem services that were close to being in consensus among the four viewpoints: (1) household/municipal use, which was ranked +2 for the environmental perspective, +4 for both the agricultural perspective and the recreation perspective, and +3 for the Native American perspective; and (2) land-based hunting, which was ranked at +2 for the recreation perspective and 0 for the remaining three viewpoints. There were also several water-based ecosystem services that were in consensus among two or three viewpoints. Water quality, for example, was highly important to the environmental perspective (+4), agricultural perspective (+3), and Native American perspective (+4), but it was not a consensus statement because of the unimportance assigned by the recreation perspective (-1).

The differences between the four viewpoints may be best highlighted by the names given to each perspective. The environmental perspective valued the regulating services higher than any other factor. Regulating services are those that support a healthy environment through attributes like high-quality water and biodiversity. Of the 9 regulating services in the Q-set, the environmental perspective ranked 8 of those in the top 9 spots on the Q-board (+2 through +4). Biodiversity conservation is of paramount importance to the environmental perspective, but it is unimportant (-1) to both the recreation perspective and agricultural perspective. The Native American viewpoint does not see biodiversity conservation (0) as important or unimportant. The agricultural perspective was named for the preference given to the four agricultural ecosystem services (commercial irrigation (+4), water for stock (+3), preserving livelihoods, lifestyles and landscapes (+3) and personal irrigation (+2)).

The Native American viewpoint, which was represented by the positive viewpoint on the third factor, was named for the high importance assigned to Native American cultural and spiritual values (+4). There is a stark contrast between the importance assigned to Native American cultural and spiritual values by the Native American viewpoint and the other three distinct viewpoints (environmental perspective (0), agricultural perspective (-4), and recreation perspective (-3)). The recreation perspective ranked 10 out of 12 of the water-based ecosystem services related to recreation in the top 14 spots (+1 to +4 on the Q-board), which is an overwhelming preference when considering the other three viewpoints. The environmental perspective ranked 3 out of 12 water-based ecosystem services related to recreation in the top 14 spots (all three were in the +1 category), the agricultural perspective also ranked 3 recreation-related ecosystem services in the top 14 spots, and the Native American perspective ranked 0 recreation-related ecosystem services in the top 14 spots.

7.2 Guidelines Used for Making Recommendations for Ecosystem Services to be Considered in Phase II

The following guidelines were used by the investigator as a tool to assist in the decision of what water-based ecosystem services should be carried forth to the second phase for non-market and market valuation: (1) ecosystem services of paramount importance (+4) to at least one of the viewpoints; (2) ecosystem services that are highly important (+3 or +4 on the Q-board) to more than one viewpoint; (3) ecosystem services that are highly important (+3 or +4) to one viewpoint, but are viewed as highly unimportant (+3 or +4) to other viewpoints; (4) ecosystem services that are conducive to non-market valuation; and (5) ecosystem services that could potentially be impacted by Forest Service management strategies.

The overarching purpose of this research was to provide public land managers with information about the importance of water-based ecosystem services to a diverse range of stakeholders, which could then be used to support development of land management strategies that are, as much as possible, publicly acceptable and economically justified, while at the same time abiding by the mission of the Forest Service. According to Gifford Pinchot, the first Chief of the Forest Service, the mission of the Forest Service is "to provide the greatest amount of good for the greatest amount of people in the long run" (US Forest Service, 2012, About Us Section: para. 2). Implicit in that quote is the multiple-use mission, but also a mission of sustainability and prudent use. Therefore, the above guidelines will help to highlight those water-based ecosystem services that land managers should concentrate on to fulfill the Forest Service mission.

Guidelines 1 and 2 will help to identify those water-based ecosystem services that are important to stakeholders and, if managed for, would likely receive public support from at least one of the viewpoints. Prudent allocation of scarce water resources could potentially improve relationships between federal land managers and local stakeholders. A transparent and informed decision-making process with regard to natural resources could help to improve these relationships, especially in situations where there is potential for conflict. Therefore, it is important to consider ecosystem services that are potentially contentious, which was the motivation for guideline 3. For example, motorized ice and snow based recreation was important to the recreation perspective (+3), but it was quite unimportant to all other factors (agricultural perspective (-2), environmental perspective (-3), Native American perspective (-4)). When navigating a potentially contentious water-resource decision that involves ecosystem service tradeoffs, it would seem to behoove the decision makers to present evidence to stakeholders that illustrates that the course of action is based on substantive information.

Guideline 4 was used because the survey instrument employed in the next phase will focus on non-market valuation via a choice modeling survey. However, the next phase could also, where possible, use traditional market valuation techniques to value certain water-based ecosystem services. For example, Native American cultural and spiritual values cannot be valued on the traditional market place because there are no products being bought or sold and, as a result, non-market valuation would be required. In contrast, commercial irrigation, as it is defined for this project, can be valued using traditional market valuation techniques.

The fifth guideline was used as a way to highlight water-based ecosystem services that may be especially relevant to land managers. Guideline 5 could also be used as a potential tiebreaker for deciding between two ecosystem services that were both suitable for the next phase of research, but due to limited time and funding, only one could be carried forward. For example, if all other aspects related to stakeholder preference were equal for conservation of rare plant species and hydropower, then the investigator would opt for conservation of rare plant species because it is an ecosystem service that could more easily be addressed by mangers on the SNF

This section will recommend several water-based ecosystem services to be valued in the next phase of research for this project. It is important to note that the recommendations were chosen using at least one of the above guidelines, but there was an inherent flexibility in the process. Each ecosystem service was not required to satisfy all the guidelines, or even any specific guideline. Also, there were water-based ecosystem services that may have met one or more of the established guidelines, but were still not included in the recommendations. The 10 recommended water-based ecosystem services presented below are in two subsections: recommendations for non-market valuation, and recommendations for market valuation.

7.2.1 Recommendations for non-market valuation

The recommendations given below are presented in decreasing order of importance for investigation in the next research phase, which means that the first recommendation is, according to the investigator, an ecosystem service that should definitely be carried forth to the next phase of research. There are eight water-based ecosystem services being recommended for non-market valuation. The four viewpoints (represented by the factor arrays) indicated that the following six[20] different water-based ecosystem services were of paramount importance (+4 on the Q-board): Commercial irrigation, household/municipal use, water quality, biodiversity conservation, Native American cultural and spiritual values, and river-based fishing. Five of the six 'most important' water-based ecosystem services for all four viewpoints are being recommended for non-market valuation in the second phase of research for this project. Commercial irrigation is not being recommended for non-market valuation, but is instead being recommended for market valuation.

1. Household/municipal use

The use of water for everyday living was important to all four viewpoints and, in two cases, it was of paramount importance. These high levels of importance satisfy guidelines 1 and 2, and the investigator feels that it would be unconscionable to not include an ecosystem service that was highly important to all viewpoints. Household/municipal use of water could potentially be subjected to market valuation because there are certain costs incurred by stakeholders that are easily measured on the market (i.e. cost of obtaining municipal water, and cost of creating and maintaining a well). However, there are certain values associated with household/municipal water that are not as easily measured on the traditional market. For example, Participant 6, who helped to define the agricultural perspective (+4 for household/municipal use) stated,

[20] Four factor arrays with two "most important" (+4) water-based ecosystem services each equals eight total possible "most important" ecosystem services for the four viewpoints, but there are only six because *household/municipal use* and *water quality* were present twice in the top two spots.

"having a good clean source of water, even though it can be cleaned up within the system…it is just the fact that the cleaner it is before it goes into the plant, the better I feel about it regardless of the total outcome, and cheap [too], because it does not cost as much to clean up the water." The benefit derived from knowing that water straight from the tap is clean is a benefit that is not captured by the traditional market. Within the study area this benefit may be especially important when considering the issues that involve the degradation of water supplies from oil and natural gas extraction (discussed in Section 1.3).

2. Water Quality

Water quality was highly important to three of the four viewpoints, which satisfies guideline 2. Water quality was also a common theme throughout the drivers discussion, with most water-based ecosystem services identified for this project being supported by high quality water, or directly impacting high quality water. Also, most participants who considered household/municipal use as 'most important' indicated that the quality of water within the study area would have a direct impact on water for household/municipal use. Lastly, water quality is a water-based ecosystem service that the Forest Service could manage for, which satisfies guideline 5.

3. Native American cultural and spiritual values

The importance of Native American cultural and spiritual values for factor 3A was +4, but for the other three factors it was either highly unimportant (-4 for the agricultural perspective, and -3 for the recreation perspective) or neutral (0) for the environmental perspective. These viewpoints with regard to Native American cultural and spiritual values satisfy guidelines 1 and 3, which suggests that this particular water-based ecosystem service be recommended for the next phase of research. However, the prospect of attaching a dollar value to Native American cultural and spiritual values is potentially an incendiary topic, because it requires one to decide their willingness to pay for an intangible aspect of life that has forever been priceless for the Native American viewpoint.

The valuation of Native American cultural and spiritual values would only happen with the support of the Native American Tribes within the study area. However, if it was decided that Native American cultural and spiritual values were not something that could be valued, the investigator believes that valuation of water quality could be a proxy, because many participants who valued Native American cultural and spiritual values as paramount indicated that high quality water is important, and in certain cases necessary, for cultural and spiritual purposes.

4. Preserving livelihoods, lifestyles, and landscapes

The benefits provided by healthy agricultural communities in the study area were viewed as important by the agricultural perspective (+3) and the recreation perspective (+2), but were seen as unimportant by the Native American perspective (-1) and neutral by the environmental perspective. The high importance assigned to this ecosystem service by two of the four viewpoints (guideline 2), and its suitability for non-market valuation (guideline 4) make it an appropriate recommendation for phase II of this research project.

5. Biodiversity conservation

Biodiversity conservation is of paramount importance to the environmental perspective, which was the only viewpoint that considered it to be important (+1 to +4 on the Q-board). Therefore, this ecosystem service satisfies guideline 1 for a recommendation to the next phase. Also, biodiversity conservation is an ecosystem service that provides numerous benefits that are not captured on the traditional market (e.g. benefit from knowing that the SNF has a wide range of biological life, from charismatic mega-fauna like the grizzly bear to the tucked away lichen living among the glaciers), which make it a good ecosystem service for non-market valuation (guideline 4). Biodiversity conservation is also an ecosystem service that can be actively managed (guideline 5). The Shoshone National Forest Draft Management Plan published by the USDA Forest Service (2012, p. 21) only mentions biodiversity once, which is in reference to the "inventoried roadless areas." According to the Plan (USDA Forest Service, 2012, p. 21), "management of roadless areas is controversial. Some advocate that enough wilderness has been designated and that multiple use management is appropriate in these areas. Others advocate that these [inventoried roadless] areas should remain in a natural and undisturbed state to maintain *biodiversity* and promote ecosystem management." Even though the Plan does not mention biodiversity outside of the *inventoried roadless areas* context, the Plan does manage for the following natural attributes of the forest that contribute to biodiversity conservation: vegetation; threatened, endangered, proposed, and candidate species; sensitive species; management indicator species; species of local concern; invasive species; and eligible wild and scenic rivers.

6. River-based fishing

The recreation perspective considered river-based fishing to be the ‘most important’ (+4), which satisfies guideline 1. River-based fishing was also important to the agricultural perspective (+2) and the environmental perspective (+1). The Native American perspective considered it to be slightly unimportant (-1). Also, river-based fishing is recommended for the next phase of research because its high market value (discussed in Section 3.2.3.2) could be complimented by a non-market valuation (guideline 4). For example, the joy of catching a native cutthroat trout from a pristine stream that has not been influenced by human activity may be worth more than fishing for the invasive lake trout out of a reservoir full of motorboats and large concrete human-made structures. River-based fishing is also something that can be managed (guideline 5), which adds to its suitability for being carried forth to the next phase of research.

7. Conservation of keystone (critical) species

Conserving keystone species within the study area was important to the environmental perspective (+3) and it was slightly important to the Native American perspective (+1). The agricultural perspective (0) was neutral and without preference, and the recreation perspective regarded the conservation of keystone species as slightly unimportant (-1). Even though the conservation of keystone species does not satisfy guidelines 1-3, guidelines 4 and 5 are satisfied by this ecosystem service. The conservation of keystone species is an ideal candidate for non-market valuation. The SNF Draft Management Plan (USDA Forest Service, 2012) does manage for, among other species, the cutthroat trout, which was one example given in the Q-set statement for conservation of keystone (critical) species.

8. Motorized ice and snow based recreation

The recreation perspective valued motorized ice and snow based recreation (+3) significantly higher than all other viewpoints (agricultural perspective –2, Native American perspective -4, and environmental perspective -3), which is an indication that it is a potentially polarizing water-based ecosystem service and, as per guideline 3, it is being recommended as an ecosystem service to be valued in the next phase. Guideline 4 can be used to justify the inclusion of this ecosystem service in the next phase for non-market valuation because, even though there are certain aspects of the motorized ice and snow based recreation (e.g. money spent on fuel and machinery) that can be valued in the traditional marketplace, there are also aspects of the ecosystem service (e.g. value of quality time with the family) that could be accounted for with non-market valuation. Also, guideline 5 suggests that those ecosystem services that are subject to management actions, which is the case for motorized and non-motorized recreation, are suitable for valuation in the following phase.

Note on biodiversity conservation, river-based fishing, and conservation of keystone (critical) species

Biodiversity conservation may be a particularly good candidate for non-market valuation during the next phase of research because it is an ecosystem service that could capture the value of other important ecosystem services in this project, such as river-based fishing and conservation of keystone (critical) species. All three of these ecosystem services are quality candidates for further consideration and valuation. However, five ecosystem services is about the maximum number of ecosystem services that could be valued using the preferred and state-of-the-art technique, choice modeling (Bennet & Blamey, 2001; Hensher et al., 2005). Therefore, it may not be possible to value each of the eight ecosystem services recommended above using non-market techniques, which would require the above recommendation of eight to be pared down.

It may be possible to pare down the above recommendation by valuing biodiversity conservation, while at the same time asking questions that gain a better understanding of what specifically about biodiversity conservation is valued by the respondent, including river-based fishing and conservation of keystone species. For example, a choice modeling survey may indicate that avid anglers have a higher willingness to pay for biodiversity conservation than other demographic groups, which would support the existence of a non-market benefit related to fishing rivers and streams that have a high level of biodiversity. Similarly, a choice modeling survey could find that there is a higher willingness to pay for biodiversity conservation in cases that specifically address certain keystone species like the whitebark pine, cutthroat trout, and beaver, which would indicate that there is a non-market value associated with keystone species.

As discussed in Section 6.1.1, the ecosystem services entitled *biodiversity conservation* and *conservation of keystone (critical) species* were included in the Q-set despite an overlap between the two, because the focus group discussions indicated that there was a difference between the two ecosystem services that was worth investigating. In the end, all of the four viewpoints ranked the two ecosystem services similarly, with only a maximum difference of one column on the Q-board. Also, the 96 participants ranked the two ecosystem services somewhat similarly with an average difference of 1.67[21]. The similarity assigned by both the viewpoints and the participants is another reason to only proceed to the next phase of research with biodiversity conservation.

7.2.2 Recommendations for market valuation

The following ecosystem services are recommended for valuation using traditional market valuation techniques.

Commercial irrigation

Commercial irrigation was an ecosystem service viewed as most important by the agricultural perspective (+4), but it was not important to the environmental perspective (-2) and the Native American perspective (0). The recreation perspective regarded commercial irrigation as slightly important at +1. Commercial irrigation satisfies guideline 1, and partially satisfies guideline 3.

Oil and natural gas extraction, and mining

None of the four viewpoints felt that oil and natural gas extraction, and mining was important. The recreation perspective and the agricultural perspective ranked it at 0, the environmental perspective ranked it as extremely unimportant (-4), and the Native

[21] The average difference in rank between biodiversity conservation and the conservation of keystone (critical) species was found by calculating the difference between the rank for each ecosystem service for each participant, and then finding the average of all of those differences.

American perspective considered this ecosystem service as slightly unimportant (-1). Despite the overall low importance assigned to this ecosystem service by the four viewpoints, the investigator recommends this ecosystem service be considered for further market valuation because of its large contribution to the economy of the study area. Oil and natural gas extraction were the largest economic generators in the study area as of 2010, a point that was discussed in Section 3.2.3.1. Furthermore, according to several participants (discussed in Section 6.4.4), oil and natural gas extraction is an industry that could potentially impact a suite of other services, such as biodiversity conservation, conservation of keystone species, water quality, and household/municipal use.

7.3 Summary

Analysis of 96 Q-sorts yielded four distinct viewpoints related to the importance of water-based ecosystem services derived from the SNF. The nature of factor analysis and orthogonal rotation ensures that the viewpoints are different; however, there are some similarities that result from certain water-based ecosystem services being ranked similarly by the four viewpoints. Understanding the differences and similarities between the four viewpoints was helpful when trying to decide the limited number of water-based ecosystem services that can be carried forward to the next phase of research. The six different water-based ecosystem services that were indicated as “most important” by the four viewpoints have been either recommended for non-market or market valuation in the second phase of research.

Chapter 8

<u>Conclusion</u>

This thesis focused on identifying and understanding the full range of perspectives that exist with regard to the importance of water-based ecosystem services derived from the Shoshone National Forest (SNF). Land management decisions regarding water resources on public land may gain more support from a broad range of stakeholders if there is a feeling that the various viewpoints related to the importance of water-based ecosystem services in the study area are being addressed. The conclusion of this thesis is composed of three short sections: (1) summary of the research findings; (2) limitations of this phase of research; and (3) call for future research to compliment the findings of this project.

8.1 Summary of the Research Findings

The objectives outlined in Section 1.2 were completed using Q-methodology. The creation of the Q-set addressed the first objective by identifying 34 water-based ecosystem services derived from the SNF that represents the full range of water benefits being provided by the natural aquatic ecosystems within the study area. The Q-set can be broken into three categories using the framework for the classification of ecosystem services by function discussed in Section 2.1.1: regulating services, cultural services, and production services. As shown in Table 6.1, the Q-set was composed of 9 regulating services, 9 production services, and 16 cultural services. Most (12 out of 16) of the cultural services were related to recreation, which is a quality of the Q-set that can be attributed to productive focus group discussions with a wide range of stakeholders in the study area.

The second objective required the investigator to identify the stakeholders that are benefiting from the gamut of water-based ecosystem services outlined in the Q-set. The investigator developed a list of stakeholders, reported in Table 5.2, which would be targeted for inclusion in the Q-sorting process. The P-set is presented in Table 6.2, and includes a total of 96 stakeholders that were surveyed between February and March of 2012. The P-set is broken into six sectors: private sector, non-governmental organizations, tribal governments, local governments, state governments, and the federal government. When Table 5.2 is compared to Table 6.2, it can be seen that almost every desired interest group was successfully recruited to complete a Q-sort. In fact, both tables are almost identical, except that Table 5.2 included the Federation of Fly Fishers (non-governmental organization), which was a group that was not surveyed because of logistical reasons. There was also a stakeholder within the Forest Service that was not surveyed but, to protect confidentiality, the comparison of the two tables will not show this missing interest group.

Objective 3 focused on understanding the relative importance assigned to the water-based ecosystem services (Q-set) by the diverse group of stakeholders (P-set) in the study area. The third objective was completed by factor analyzing the 96 Q-sorts collected. Data analysis yielded four distinct perspectives, which were interpreted to provide a nuanced description of the level of importance assigned to the full range of water-based ecosystem services derived from the SNF by each different viewpoint.

The names given to each viewpoint were, in order of factor stability, the environmental perspective, agricultural perspective, Native American perspective, and recreation perspective. Those that adopted the environmental perspective felt that the regulating water-based ecosystem services were most important, and that those ecosystem services that consumed water (i.e. production services) were the most unimportant. The agricultural perspective assigned high importance to the four ecosystem services that were related to agriculture (i.e. water for stock, commercial irrigation, personal irrigation, and preserving livelihoods, lifestyles and landscapes). The Native American viewpoint felt that the Native American cultural and spiritual values were the 'most important', but the participants that loaded onto this viewpoint also valued those ecosystem services that were likely to support their economy, such as water for stock and hydropower. The recreation perspective, perhaps the most aptly named, valued recreation-related ecosystem services in 10 of the 14 positively-important spots on the Q-board.

The fourth, and final, objective was focused on understanding how stakeholders perceived climate change and other factors as potentially influencing their ability to receive their two 'most important' water-based ecosystem services. The discussion in Section 6.4.2 detailed how stakeholders perceived climate change as a potential threat to a variety of ecosystem services that were ranked 'most important' by the 96 Q-sorters. In general, there was a diverse range of perspectives related to climate change, which ranged from concerned to dismissive. As discussed in Section 6.4.3, there were several stakeholders that conceded that if the climate change trends presented to them were to continue, then there would be serious ramifications. However, there were also several caveats attached to those admissions that noted there was a lack of evidence to suggest that the trends are: (a) separable from natural climate cycles; (b) going to continue; and (c) actually happening at the present time.

Section 6.4.4 discussed those drivers not related to climate change that were perceived as impacting, positively or negatively, the flow of stakeholders' two 'most important' water-based ecosystem services. There were various *other factors* raised by stakeholders, but water quality, management and regulations, pressure from conservation groups, pressure to develop residentially and industrially, agriculture, and other competing uses of water were among the most cited drivers.

8.2 Limitations of this Research Project

This section will discuss the limitations of this research, and an aspect of the execution of the research method that could potentially be improved. The first limitation, and perhaps largest, is that these results are not representative of the greater population. For example, 35 participants loaded onto the environmental perspective, which means that 36 percent (35 out of 96) of the participants agreed with the viewpoint illustrated in the factor array for the environmental perspective. However, in no way can this research assert that 36 percent of the study area population agrees with the viewpoint expressed by the environmental perspective's factor array. Despite this limitation, it can be confidently asserted that the environmental perspective exists in the study area because of its high factor reliability. Therefore, land management decisions made that consider the viewpoint of the environmental perspective will appeal to some *portion* of the population but, at this point, the size of that portion is unclear.

Another limitation of this research, which also happens to be one of its strengths, is that this research is study area specific, which means that the viewpoints regarding the importance of water-based ecosystem services cannot reliably be applied to another location. For example, the agricultural viewpoint recognized the importance of preserving livelihoods, lifestyles, and landscapes, but such a viewpoint may not exist in another location where agriculture is not present. Similarly, the inclusion of glacier-based services in the Q-set would obviously not work when considering a tropical ecosystem devoid of glaciers.

There was one aspect of the execution of this research project that could have been improved upon. This aspect was the follow-up conversation, which is meant to give the participant a chance to explain their Q-sort by indicating certain thought processes that led to the layout of their particular Q-sort. The follow-up discussion did take place, however, it was focused on understanding the factors that stakeholders felt were potentially going to impact their ability to receive their 'most important' water-based ecosystem services. This aspect of the project was important to the investigator and funding agent, and therefore could not have been forgone. The investigator believed that an additional conversation about the reasoning behind a participant's Q-sort would have been too burdensome for the participant, which is why it was not made part of the survey process.

Despite this limitation, the drivers discussion did, in most cases, adequately explain why a participant Q-sorted in their unique way. There were times, though, when the investigator could not make connections within a viewpoint that could have potentially been made with a more extensive follow-up conversation. For example, the recreation perspective considered water quality to be slightly unimportant (-1) which, according to some qualitative data, is due to the pressure from conservation groups asserting that recreational activities negatively impact water quality. There is a chance that there may have been some other thought process at play that could have been uncovered with a more extensive follow-up conversation.

8.3 Call for Future Research

This section will discuss other potentially beneficial research that could compliment or expand upon the current research. There are three more planned phases of research that are intending to use this research as its foundation. The second phase, as discussed in Chapter 7, will take several water-based ecosystem services that were important in this project and apply non-market and market valuation techniques that will result in an economic value for those ecosystem services. A planned third phase of research will apply climate change models to those ecosystem services to estimate changes in the provision of those ecosystem services as a result of climate change. A fourth phase of research has also been planned, which intends to use information from the first three phases to create a decision-support tool for managers that would facilitate socio-economic evaluation of alternative land management strategies in terms of their effects on provision of water-based ecosystem services.

There is also a need for future research that incorporates the ecosystem services framework into a social vulnerability assessment to climate change. For example, Turner et al. (2003) noted that an essential element of a vulnerability analysis is a consideration of the human-environment system (discussed in Section 2.2.2.2). Therefore, using a vulnerability model that considers the complex relationship between natural and human systems is essential. The report by Rice et al. (2012), which was discussed in Section 3.4.2, concentrates primarily on the vulnerability of certain aspects of the environment (e.g. water quality) to climate change without considering how those ecosystem services are important to society. Combining the report by Rice et al. (2012) and the information gathered during this project may facilitate a detailed understanding of the potential impacts of a changing climate on both natural and human systems. For example, a loss in cutthroat trout habitat would negatively impact river-based fishing, which has implications for people within and outside the study area, including those whose preferences align with the recreation perspective.

The investigator also sees utility in using the information gathered from this project to support survey research that could gain a better understanding of the prevalence of specific viewpoints. For example, a survey could include four land-management plans that were built around the four distinct viewpoints yielded from this Q-methodological study, which asked respondents to indicate their preferred plan. That survey could be administered to the study area, which would highlight the popularity of each of the management plans. Such a study would then make it possible to assert the *portion* of the study area population that supports each viewpoint.

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Appendix A: Breakdown of Unemployment Rates and Per Capita Income by County

Entity	Unemployment Rate[a] (June 2012)	Per Capita Income[b] (1969-2010)
United States of America	8.2%	$39,937
State of Wyoming	5.5%	$44,961
State of Montana	6.2%	$35,053
Big Horn County, WY	6.3%	$31,073
Fremont County, WY	6.9%	$37,696
Hot Springs County, WY	4.7%	$39,480
Park County, WY	5.3%	$44,762
Washakie County, WY	5.4%	$39,135
Carbon County, MT	4.8%	$33,640
Big Horn County, MT	11.7%	$25,966
Study Area	*6.44%	**35,965

Notes: *Unemployment rate for the study area was found by averaging the unemployment rate of the seven counties that contribute population to the study area.

**Per Capita income for the study area was calculated by averaging the per capita income of the seven counties that contribute population to the study area.

Sources: a. BLS (2012)

b. BEA (2010b)

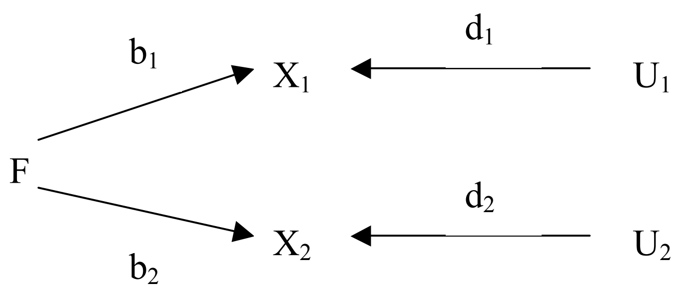
Appendix B: Factor Analysis

This Appendix discusses certain aspects of factor analysis, both in the context of Q-methodology and R-methodology, as a way to facilitate the reader's understanding of how factor analysis is used in Q-methodology.

B.1 A Basic Factor Model

Figure B.1 is an illustration of a "two-variable, one-common factor model," which conveys how the goal of factor analysis is met via the explanation of a set of observed variables with a smaller number of unobserved variables.

Figure B.1 Path model for a two-variable, one-common factor model



Source: Kim and Mueller (1978, p. 13).

In the above model, X_1 and X_2 represent the observed variables, and F, U_1 and U_2 represent the source variables, where F is the common factor, and U_1 and U_2 are unique factors. The source variables can also be known as unobserved variables, underlying factors, hypothetical constructs, hypothetical variables, or hypothetical factors. The b_1, b_2, d_1, and d_2 represent the weights that must be applied to the unobserved variables to end up at the observed variables. The algebraic representation of the observed variables is as follows:

$$X_1 = b_1F + d_1U_1 \qquad [1.1]$$

$$X_2 = b_2F + d_2U_2 \qquad [1.2]$$

The main lesson is that, even though there are three factors (unobserved variables) contributing to the existence of the observed variables, only one (common factor F) has the ability to explain anything about both of the observed variables. Hence, in this basic situation, factor analysis has completed its goal of explaining a number of observed variables (two) with a smaller number of unobserved variables (common factor F).

B.2 Covariance, Mean, Variance and Standard Variables

Covariance is an important concept in factor analysis, and is defined as follows:

$$Cov(X,Y) = \frac{\sum[(X_i - \overline{X})(Y_i - \overline{Y})]}{N} \qquad (i = 1, 2, \ldots, N) \qquad [2.1]$$

where X and Y are observed variables, and $\overline{X}$ and $\overline{Y}$ are the means of X and Y, respectively, and N is equal to the number of observed variables. Covariance "measures the extent to which values of one variable [X] tend to covary with values of another variable [Y]. The *covariance* between standardized variables (with a mean of 0 and a variance of 1) has a special name: *correlation coefficient* or *product-moment (Pearson's) correlation coefficient*" (Kim & Mueller, 1978, p. 16, emphasis in original).

Statistically, there are two important properties that variables can have: mean and variance. The mean and variance are calculated using the following equations:

$$Mean = \frac{\sum(X_i)}{N} \qquad (i = 1, 2, \ldots, N) \qquad [2.2]$$

$$Variance = \frac{\sum[X_i - \overline{X}]^2}{N} \qquad (i = 1, 2, \ldots, N) \qquad [2.3]$$

When correlating variables, it is important that they are standardized or normalized variables, which implies that all variables (both observed and unobserved) have a mean of 0 and a variance of 1. According to Kim and Mueller (1978, p. 16):

> Any variable can be transformed into such a standardized variable by simply subtracting the mean from the observed values and dividing the resulting values by the square root of the variance. Therefore, we do not lose any generality by dealing with only standardized variables.

When using standardized variables, the definition of [2.1] and [2.3] can be reduced because the means, with a value of zero, can be dropped out of the equation:

$$Cov(X,Y) = \frac{\sum[(X_i)(Y_i)]}{N} \qquad (i = 1, 2, \ldots, N) \qquad [2.4]$$

$$Variance = \frac{\sum[X_i]^2}{N} \qquad (i = 1, 2, \ldots, N) \qquad [2.5]$$

When correlating two standard variables, the value of the correlation coefficient ranges between 1 and -1, which represents the similarity between two variables. A correlation coefficient approaching the value of 1 is indicative of increasing similarity, a correlation coefficient approaching the value of -1 is indicative of increasing dissimilarity, and a correlation coefficient with a value of 0 is indicative of statistical independence (or no similarity between the variables).

B.3 Derivation of the Correlation Coefficient in Q-methodology

It has been established that the covariance equation, as shown in [2.4], for standard variables is the same as the correlation coefficient, however, the equation for the correlation coefficient in Q-methodology is, for convenience, presented as follows:

$$r = \frac{1 - \sum_{N=1}^{N} d^2}{2Ns^2} \qquad [3.1]$$

The following discussion is summarized from Brown (1980) and it is meant to illustrate how equations [3.1] and [2.4] are the same under conditions of equal means and variances, as is the case with standard variables and forced-distribution Q-sorts.

As previously noted, in Appendix B.2, the covariance, correlation coefficient, and product-moment (Pearson's) correlation coefficient are the same when dealing with standard variables. In order to illustrate this point, it is appropriate to start with Pearson's product-moment correlation coefficient, which for two Q-sorts, X and Y, can be expressed as follows:

$$r_{xy} = \frac{\sum xy}{\sqrt{(\sum x^2)(\sum y^2)}} \qquad [3.2]$$

Where $x = X - \overline{X}$ and $y = Y - \overline{Y}$, i.e., where x and y are deviation scores around the mean of their respective scores in Q-sorts X and Y.

Brown (1980, p. 267) noted that the "correlation coefficient can be expressed in a number of ways," and [3.2] is one such way. The representation of the correlation coefficient in [3.2] is born out of the geometry of correlation, and its derivation involves the calculation of the square root of the tangent of both variables, X and Y. In the interest of avoiding a somewhat-lengthy digression, the reader is referred to Brown (1980, p. 267-272) for a detailed explanation of the derivation of [3.2].

Equation [3.2] can be modified, without changing its value, by multiplying any term by (N/N), where N is the size of the Q-set. Since (N/N) = 1, then multiplying any term by 1 is inconsequential and, now, [3.2] can then be expressed as:

$$r_{xy} = \frac{\sum xy}{\sqrt{[(N/N)\sum x^2][(N/N)\sum y^2]}}$$

$$r_{xy} = \frac{\sum xy}{\sqrt{[N(\sum x^2/N)][N(\sum y^2/N)]}} \qquad [3.3]$$

As previously shown, the following expression is equal to the variance of a standard variable:

$$\frac{\sum x^2}{N} = \frac{\sum (X - \overline{X})^2}{N} = s_x^2$$

Now, [3.3] can be expressed as follows:

$$r_{xy} = \frac{\sum xy}{\sqrt{(Ns_x^2)(Ns_y^2)}}$$

$$r_{xy} = \frac{\sum xy}{Ns_x s_y} \qquad [3.4]$$

Where s_x and s_y are the standard deviations of Q-sorts X and Y and N is the Q-set size. According to Brown (1980, p. 273), for expression [3.4]:

> Pearson's *r* calls for the multiplication of *x* values and *y* values, but this can be expressed in terms of the simpler operation of subtraction. If the difference in raw scores can be expressed as D = X – Y, then differences in deviation scores can be expressed as d = $x - y$.

Considering this, the variance of differences is expressed by the following:

$$s_d^2 = \frac{\sum (x-y)^2}{N} = \frac{\sum (x^2 + y^2 - 2xy)}{N}$$

$$s_d^2 = \frac{\sum x^2}{N} + \frac{\sum y^2}{N} - \frac{2\sum xy}{N}$$

$$s_d^2 = s_x^2 + s_y^2 - \frac{2\sum xy}{N} \qquad [3.5]$$

The last term in [3.5] can be multiplied by $s_x s_y / s_x s_y = 1$ (both s_x and s_y are standard deviations, which equal 1 for standardized variables) without changing its value, which results in the following:

$$s_d^2 = s_x^2 + s_y^2 - 2(\frac{\sum xy}{N s_x s_y}) s_x s_y \qquad [3.6]$$

The term within parentheses in [3.6] is defined as r in [3.4]. Hence,

$$s_d^2 = s_x^2 + s_y^2 - 2 r_{xy} s_x s_y$$

Solving for *r* yields:

$$r_{xy} = \frac{s_x^2 + s_y^2 - s_d^2}{2 s_x s_y} \qquad [3.7]$$

The subscripts *x* and *y* can be ignored in [3.7] because the variances for X and Y are equal, as previously mentioned. Therefore, [3.7] can be reduced:

$$r_{xy} = \frac{s^2 + s^2 - s_d^2}{2s^2} = \frac{1}{2}(\frac{s^2}{s^2} + \frac{s^2}{s^2} - \frac{s_d^2}{s^2})$$

$$r_{xy} = \frac{1}{2}(2) - \frac{1}{2}(\frac{s_d^2}{s^2})$$

$$r_{xy} = 1 - \frac{s_d^2}{2s^2} \qquad [3.8]$$

If a difference score is D = X – Y, difference deviation scores can be expressed as d = D- $\overline{D}$. A rule of basic statistics states that subtracting a constant from a set of numbers will affect the mean, but it will not have any impact on the variance. As a result, the following is true: $s_D^2 = s_d^2$, and

$$s_d^2 = \frac{\sum d^2 - [(\sum d)^2 / N}{N}$$

$$s_d^2 = \frac{\sum d^2}{N} - (\frac{\sum d}{N})^2 \qquad [3.9]$$

But $\sum d = \sum (x - y)$, and since the sum of a variable is equal to N times the mean of the variable,

$$\sum d = \sum x - \sum y = N\overline{x} - N\overline{y} = N(\overline{x} - \overline{y})$$

If the means are equal, as in forced-distribution Q-sorts, then $\overline{x} = 0$, $\overline{y} = 0$, and $\overline{x} - \overline{y} = 0$; consequently, $\sum d = 0$, and $(\sum d/\mathrm{N})^2 = 0$. Substituting in [3.9] results in:

$$s_d^2 = \frac{\sum d^2}{N} - 0$$

$$s_d^2 = \frac{\sum d^2}{N} \qquad [3.10]$$

Finally, substituting [3.10] into [3.8] results in the following:

$$r_{xy} = 1 - \frac{s_d^2}{2s^2}$$

$$r_{xy} = 1 - \frac{\sum d^2}{2Ns^2} \qquad [3.11]$$

It may still be unclear how [3.11] and [2.4] are the same equation, because the derivation of [3.11] was started with Pearson's product-moment correlation coefficient, and not with [2.4]. Considering [3.4] and the fact that the standard deviation of any standardized variable is the square root of the variance of that standardized variable, which is equal to 1; it becomes apparent that [3.4] takes on the exact same form as [2.4], because the standard deviations, with a value of 1, will have no impact on the equation.

B.4 Standardization and Correlation of Variables for an R-Study

In order to correlate variables in an R-study it is first necessary to standardize the variables (a process that is articulated in Appendix B.2). The following algebraic example is adapted from Brown (1980, p. 272), and it illustrates the process of standardizing two variables, A and B. The values of A and B would be taken from a matrix of raw data, like Table 4.2 shown in Section 4.2.5.2.

$$z_a = \frac{A - \overline{A}}{s_a} \qquad z_b = \frac{B - \overline{B}}{s_b} \qquad [4.1]$$

Where A and B would be the raw-data values, $\overline{A}$ and $\overline{B}$ are the means of the raw-data values, and s_a and s_b are the standard deviations for A and B, respectively. The mean is simply the average of all the values for a trait, and the standard deviation (using trait A as an example) is computed using the following equation:

$$s_a = \sqrt{\frac{\sum (A - \overline{A})^2}{N}} \qquad [4.2]$$

To illustrate the processes of standardization and correlation in R-method, a hypothetical example is presented in Table B.4.1 below. Where a population of 3 people is measured in two traits. Trait A represents the age of the participants, and trait B represents the number of grey hairs on the head of each participant. Table B.4.1 illustrates both the raw-data scores (A and B) and the normalized scores (z_a and z_b).

For trait A, the mean is 60, and the standard deviation is 24.49. For trait B, the mean is 500, and the standard deviation is 408.25. Using this information and [4.1], it is possible to standardize the raw data scores for both traits.

Table B.4.1 Hypothetical R-Data matrix

Traits or Tests

		A	B	z_a	z_b
Participants	1	30	0	-1.22	-1.22
	2	60	500	0	0
	3	90	1000	1.22	1.22

Using the hypothetical data presented in Table B.4.1, calculating the correlation coefficient between traits A and B is straightforward:

$$r_{z_a z_b} = \frac{\sum z_a z_b}{N} \qquad [4.3]$$

$$r_{z_a, z_b} = 2.98/3.00 = 0.99$$

The value of *r,* in this example, reflects a nearly perfect correlation between age and grey hair. In fact, inspection of the raw data shows a perfect correlation between the two variables. A correlation coefficient value of 0.99, instead of 1.00, was due to rounding errors.

B.5 Communality and Reliability

The concept of communality in Q-methodology refers to "the percentage of a person's Q-sort response associated with the responses of the other subjects in the study" (Brown, 1980, p. 211). Kim and Mueller (1978) explained that in an orthogonal factor model, which is the case in Q-methodology, the communality is equal to the sum of the squared factor loadings.

Reliability of a Q-sort refers to the amount of the Q-sort that is representative of the attitude of the sorter. Brown (1980, p. 289) explained that in Q-methodology, "it has generally been found satisfactory to use the test-retest reliability coefficient since it provides an operational measure of the extent to which a person is consistent with himself." Brown (1980) recommended the value of 0.80 as the standard amount of reliability in a Q-sort, which is a recommendation that is reinforced by PQMethod's use of 0.80 for the "average reliability coefficient." In other words, if a participant was asked to do the same Q-sort twice, the two Q-sorts would correlate with a value of 0.80, which would make the response 80 percent reliable. The remaining 20 percent would be due to error, "which might be due to a mood change, the vicissitudes of memory, a different reading of some of the statements, or other "random" effects" (Brown, 1980, p. 234). It should be noted that the generally accepted reliability of 80 percent is conservative when one considers a study done by Frank (1956), which found 93 to 97 percent reliability for 10 subjects that twice completed a Q-sort with 100 statements.

The percentage of a Q-sorter's response that is considered reliable can then be broken down into components of communality and specificity. According to Brown (1980, p. 234), reliability can be represented as follows:

$$r_{xx} = h^2 + s_p^2 \qquad [5.1]$$

Where r_{xx} is the reliability (0.80 is using Brown's (1980) recommendation), which is the same as the correlation of some variable x with itself, h^2 is communality, and s_p^2 is the notation for specificity, which is the amount of the response of a Q-sorter that is unique but still reliable. Subscript p in the term for specificity is used to differentiate from the notation for the error (s_e^2) that contributes to a respondents Q-sort. By shuffling terms, communality can be represented as:

$$h^2 = r_{xx} - s_p^2 \qquad [5.2]$$

This explanation of communality is effective in showing how communality is a function of the reliability coefficient and the specificity, however, it does not show how the communality is the sum of the factor loadings for some variable. In order to illustrate communality more clearly, it may be best to use the factor loadings for subjects 1 and 9 of Brown's (1980, p. 233) Lipset example. The loadings for subjects 1 and 9 on the seven extracted factors for the Lipset example are shown in Table B.5.1:

Table B.5.1 Factor loadings for subject 1 and 9

		Factors						
		A	B	C	D	E	F	G
Subject	1	-.21	.26	.60	.25	.25	-.18	.09
	9	-.04	.12	-.09	.00	.47	.00	.03

The communality for subject 1 is as follows:

$$h^2 = (-.21^2) + (.26^2) + (.60^2) + (.25^2) + (.25^2) + (-.18^2) + (.09^2) = .63 \qquad [5.3]$$

The communality for subject 9 is as follows:

$$h^2 = (-.04^2) + (.12^2) + (-.09^2) + (.00^2) + (.47^2) + (.00^2) + (.03^2) = .24 \qquad [5.4]$$

It now becomes evident that the communality is equal to the sum of the squared loadings, which represents the *communality* of each subject to the rest of the Q-sorters. Also, if using Brown's (1980) recommendation of 0.80 for the reliability coefficient, then finding a subject's specificity is as simple as isolating s_p^2 in equation [5.1]. For subject 1:

$$
\begin{aligned}
s_p^2 &= r_{xx} - h^2 \\
&= 0.80 - 0.63 \\
&= 0.17
\end{aligned}
$$

The specificity value for subject 1 indicates that of the 80 percent of their response that is reliable, 17 percent is unique or *specific* to them.

B.6 Components of Variance

Without explicitly saying so, appendix B.5 discussed the three components (communality, specificity, and error) that make up the total variance of a Q-sort and the study (sum of the Q-sorts). Watts and Stenner (2012, p. 98, emphasis in original) explained,

> The first is *common variance.* This is the proportion of the meaning and variability in a Q-sort or study that is *held in common* with, or by, the group. The second is *specific variance.* This is the variance that is particular to specific persons and to specific Q-sorts. It reflects individuality of the individuals involved. The third is *error variance.* This is produced by random error and by the imperfections that all methods and systems of data gathering introduce.

The process of factor extraction yields a number of *common factors* that explain the *common variance* of the correlation matrix.

Using subject 1 from Appendix B.5 as an example, the total variance of their Q-sort response would be:

$$
\begin{aligned}
total \text{ var} iance &= h^2 + s_p^2 + s_e^2 \\
&= 0.63 + 0.17 + 0.20 \\
&= 1
\end{aligned}
$$

Notice that the value of 0.20 for the error variance is dependent on the value used for the reliability coefficient, which in this case is 0.80.

B.7 Explained Variance

Appendix B.2 defined variance, and Appendix B.6 discussed the three components of variance in the context of Q-methodology. However, there has not been any discussion of the connection between factor loadings and the variance. Understanding the derivation of the variance can illustrate, in a more in-depth way, how the two are connected. The following derivation of the variance is taken from Kim and Mueller (1978).

Considering the equation for variance defined by [2.5], and the definition of the observed variable in [1.1], then the variance can be defined by the following:

$$Var(X_1) = \frac{\sum [b_1 F + d_1 U_1]^2}{N} \qquad [7.1]$$

Simple expansion will create a new equation that can be written as:

$$Var(X_1) = \frac{\sum [b_1^2 F^2 + d_1^2 U_1^2 + 2(b_1 d_1 F U_1)]}{N} \qquad [7.2]$$

Here, for simplicity, it is necessary to introduce the "expectation notation E as an abbreviation for adding all the values and dividing that sum by the total number of cases" (Kim & Mueller, 1978, p. 15). Therefore, using the expectation notation, the variance of X_1 is as follows:

$$Var(X_1) = E[b_1^2 F^2 + d_1^2 U_1^2 + 2(b_1 d_1 F U_1)] \qquad [7.3]$$

This equation can again be expanded, when one considers that "the expectation of a constant is the constant, the constants may be factored out as follows" (Kim & Mueller, 1978, p. 17):

$$Var(X_1) = b_1^2 E[F^2] + d_1^2 E[U_1^2] + 2 b_1 d_1 E[F U_1] \qquad [7.4]$$

Here it is important recognize that "the terms associated with the expectation notation have previously been defined as either variances or covariances" (Kim & Mueller, 1978, p. 18). Therefore, the variance of X_1 can be defined once more as:

$$Var(X_1) = [b_1^2 Var(F) + d_1^2 Var(U_1) + 2(b_1 d_1 Cov(F, U_1)] \qquad [7.5]$$

This equation can be simplified in this situation because the Cov(F, U_1), which is the correlation between the common factor and the unique factor, is 0. The covariation of 0 is also evident when considering the lack of direct connection between F and U_1 in Figure B.1. Therefore, the variance of X_1 is:

$$Var(X_1) = [b_1^2 Var(F) + d_1^2 Var(U_1)] \qquad [7.6]$$

Since all variables being correlated are standardized, the equation is simplified:

$$Var(X_1) = b_1^2 + d_1^2 \qquad [7.7]$$

This can be interpreted as follows: The variance of X_1 that is explained by common factor F is equal to the square of the weight (b_1^2) associated with common factor F, and the variance explained by unique factor U_1 is equal to the square of the weight (d_1^2) associated with unique factor U_1. Combining the square of both weights will yield the total variance of X_1, which is 1. It should be noted that the variance equation represented by [7.7] does not include a term for any error in sampling, or in the context of Q-methodology, error by the Q-sorter. This is because [7.7] is taken from Kim and Mueller (1978), and they stated that their factor analytic example would assume no error in sampling. The following appendix will elaborate on the error term.

B.8 Centroid Factor Analysis vs. Principal Components Analysis (PCA)

Discussing the difference, in detail, between factor analysis and PCA is no small task, and it is an endeavor that will not be undertaken here. For an in-depth discussion of the difference between the two techniques, the reader is referred to Kline (1994) and Jolliffe (2002). This appendix will focus on two differences: the number of solutions that result in each technique, and the nature of the solutions offered by each technique.

Watts and Stenner (2012, p. 99) noted that, "PCA is not factor analysis and components are not factors." The key difference, in the context of Q, between the two methods is that PCA "will resolve itself into a single, mathematically *best* solution, which is the one that *should* be accepted" (Watts & Stenner, 2012, p. 99, emphasis in original). It is established in Section 4.2.5.4 on factor rotation that, in factor analysis, there are an infinite number of factor sets that can explain a correlation matrix. The purpose of rotation in factor analysis is to find the solution that best describes the data, which is a process that is both mathematical and theoretical. The "take it or leave it" quality of PCA may sound simple and enticing, however, Watts and Stenner (2012, p. 99) argued that it "deprives us of the opportunity to properly explore the data or to engage with the process of factor rotation in any sort of abductive, theoretically informed or investigatory fashion." Watts and Stenner (2012) also noted that most Q-methodologists do not necessarily equate the best mathematical solution with the most meaningful or informative solution.

The second difference between the two techniques is the composition of the resulting factors or components. In factor analysis, the observed variables are defined by a combination of common factors and unique factors, as illustrated by Kim and Mueller (1978) and here in Figure B.1, Appendix B.1. Jolliffe (2002) expressed the composition of an observed variable in factor analysis using different notation:

$$x_1 = \lambda_{11} f_1 + \lambda_{12} f_2 + \ldots + \lambda_{1m} f_m + e_1 \qquad [8.1]$$

where x_1 is an observed variable, λ_{1m} are constants, which are unique to each variable and are known as factor loadings, f_m are the common factors, and e_1 is error term, sometimes called the specific factors. As will be described below, the error term here is synonymous with the specific factors, and it does not include the error variance discussed in Appendix B.6.

Equation [8.1] is only presented to make some connections between terminology used in Appendix B.1, B.5, and the current Appendix. Note that [1.1] is the definition of an observed variable in a factor model that has only one common factor, and [8.1] is a situation where there are multiple (m) factors. If [8.1] is rewritten as a one-common factor solution:

$$x_1 = \lambda_{11} f_1 + e_1 \qquad [8.2]$$

Now [8.2] and [1.1] are almost the same, except the notation e_1 in [8.2] is used instead of $d_1 U_1$ in [1.1]. Therefore, the error term used by Jolliffe (2002) is the same as the unique-factor term used by Kim and Mueller (1978), and the specificity concept discussed by Brown (1980). The error term used by Jolliffe (2002) should not be confused with the error term (s_e^2) discussed in Appendix B.5, or the error variance discussed in Appendix B.6, which are in reference to random measurement error that is assumed to be inherent in Q-sorting.

The error term used by Jolliffe (2002) in factor analysis is an attribute that distinguishes it from PCA. Jolliffe (2002, p. 159, emphasis in original) explained,

> In PCA, if any individual variables are almost independent of all other variables, then there will be a PC [principal component] corresponding to each such variable, and that PC will be almost equivalent to the corresponding variable…In contrast, a common factor in factor analysis must contribute to *at least two* of the variables, so it is not possible to have a 'single

variable' common factor. Instead such factors appear as specific factors (error terms) and do not contribute to the dimensionality of the model.

In other words, in PCA there is no error term because every variable will be explained by a resulting principal component, even if the principal component can only explain one variable.

B.9 Statistically Distinguishable Statements

The results printout created by PQMethod devotes a section to the statements for each rotated factor that are classified as "distinguishing statements," which are those statements for a factor that have a z-score which is *statistically different* from the z-score of the same statement for all other factors. In order to determine if statement scores are statistically different, the investigator must first find the difference in standard error of the factors. The following equation adapted from Brown (1980, p. 298) can be used to find difference in standard error between two orthogonal factors, A and B:

$$SED_{A-B} = \sqrt{SE_A^2 + SE_B^2} \qquad [9.1]$$

Where $SE_A = s_x\sqrt{1 - r_{AA}}$ and is the standard error of factor A, s_x is equal to the standard deviation of the forced distribution, which is the square root of the variance of the forced distribution shown in Section 4.2.5.2, and r_{AA} is the reliability of the factor A (referred to as the "composite reliability" in PQMethod), which is expressed by (Brown, 1980, p. 292):

$$r_{AA} = \frac{0.80p}{1 + (p-1)0.80} \qquad [9.2]$$

Where p is equal to the number of participants that load onto factor A, and the constant is the test-retest reliability coefficient (or average reliability coefficient in PQMethod), which was described in Appendix B.5.

Since a factor's reliability and standard error are a function of the number of people that load onto it, then the difference in standard error must be calculated between all rotated factors. For example, if a study yields four rotated factors, then there are 6 combinations of factors and six differences in standard error that need to be calculated ($SED_{A\text{-}B}$, $SED_{A\text{-}C}$, $SED_{A\text{-}D}$, $SED_{B\text{-}C}$, $SED_{B\text{-}D}$, and $SED_{C\text{-}D}$).

Once the differences in standard error have been calculated between all factor combinations, the investigator can inspect the z-scores for all statements to see if they are statistically distinguishable. For example, if the difference in z-scores for statement 1 between factor A and B is greater than the $SED_{A\text{-}B}$ it means that statement 1 for factor A is statistically distinguishable from statement 1 for factor B. However, the difference in z-scores for statement 1 between factor A and C and the difference in z-scores for statement 1 between factor A and D would also have to be greater than $SED_{A\text{-}C}$, and $SED_{A\text{-}D}$, respectively, if an investigator wanted to assert that statement 1 for factor A is statistically different from all other factors. Luckily for the investigator, PQMethod does these calculations and indicates which statements are distinguishable.

The purpose and meaning of this Appendix can be extracted from Brown's (1980, p. 298) statement:

> The standard error of measurement, as given in expression [$SE = s_x\sqrt{1 - r_{xx}}$] serves to locate the probable range within which true factor scores are expected to be found, and its use can also be extended in determining the limits within which differences in true scores (e.g., between factors) can be expected to be found.

In other words, in order to determine if a Q-sort is representative of the true sentiments of the Q-sorter, an investigator must account for some level of error that may have occurred during the sorting process. Likewise, standard error must be considered if the difference of statement placement between two factor arrays is to be considered a true reflection of different viewpoints.

Appendix C: The concourse of 23 water-based ecosystem services derived from the Shoshone National Forest

1. **Personal Irrigation:** The water supplied by the Shoshone National Forest (SNF), either via surface water or groundwater recharge, can be used to irrigate gardens and lawns.

2. **Commercial Irrigation:** The water supplied by the SNF can be used to irrigate commercial crops.

3. **Water for Stock:** Water supplied by the SNF can be used for the watering of stock.

4. **Whitewater River Recreation:** The rivers throughout the study area can be used for whitewater recreational activities. Some include: rafting, kayaking/canoeing, stand-up paddle boarding, tubing, body boarding, and surfing.

5. **Scenic River Recreation:** The rivers throughout the study area provide for scenic river recreational activities. Some include: kayaking/canoeing, rafting, river access hiking, picnicking, and bird watching.

6. **Lake/Reservoir Recreation:** The lakes and reservoirs supplied by the SNF provide for recreational activities. Some include: water skiing, wakeboarding, kneeboarding, skurfing, tubing, sailing, motorboating, parasailing, and kiteboarding.

7. **Facilitation of Land-Based Recreation:** Water provided by the SNF is used for the facilitation of land-based recreational activities. For example, the watering of golf courses and the water used to make snow for the Sleeping Giant Ski Area.

8. **River-based Fishing and Hunting Recreation:**The rivers throughout the study area can be used for fishing and hunting. The SNF provides high quality fish and waterfowl habitat. Facilitating the harvest of fish and waterfowl to be consumed for personal need.

9. **Lake/Reservoir Fishing and Hunting Recreation:** The lakes and reservoirs supplied by the SNF provide for fishing and hunting recreational opportunities.

10. **Non-Motorized Ice and Snow Based Recreation:** The ice and snow within the study area can be used for a number of non-motorized winter recreational activities. Some include: skiing, snowboarding, ice climbing, winter camping, and snowshoeing.

11. **Motorized Ice and Snow Based Recreation:** The ice and snow within the study area can be used for motorized winter recreational activities like snowmobiling.

12. **Hydropower:** The water supplied by the SNF is used to generate hydropower that is supplied to users at market cost.

13. **Drinking/Household Water:** Water provided by the SNF, via surface water and groundwater recharge, can be used for drinking and other household use.

14. **Mining Use:** Groundwater recharged by the SNF is used in the extraction of natural gas and oil, and to a lesser extent, in the mining of coal, bentonite, and gypsum.

15. **In-stream Flow:** The water from SNF, which is not consumed by humans, can provide a healthy river environment that benefit many species, promote biodiversity conservation, and filtration. For example, aquatic and riparian areas fed by the SNF provide habitat for a diversity of species, and genetic variation within species. Species diversity may help maintain ecosystem structure, processes and functions. Also, wetlands within the study area rely on in-stream flow and they play a crucial role in the filtering of fresh water, including the removal of various chemicals and potentially toxic elements.

16. **Cultural and Spiritual Values:** The rivers and lakes in and around the SNF have cultural, spiritual, and ceremonial purposes.

17. **Glacial Tourism Services:** The glaciers within SNF are the largest within the lower 48 States, both in quantity and area, which attracts both tourists and locals to the area for glacier sightseeing.

18. **Glacier Melt Water:** The glaciers within SNF provide melt water throughout the growing season, but especially during the late season when water demand is high. Glacial melt water also contributes to regulating water temperature.

19. **Education:**The aquatic habitats and water-based ecosystem processes within the study area can be used to improve objective knowledge of natural and social sciences, which include biology, botany, hydrology, and history.

20. **Physical and Mental Challenge:** The environment within the study area can provide opportunities for physical and mental challenge, both of which can have various health benefits.

21. **Artistic and Aesthetic Values:**The rivers and lakes in an around the SNF can provide inspiration. For example, a scenic water vista can provide the motivation for an artist's work.

22. **Fighting Forest Fires:** Water provided by the SNF can be used for the fighting of forest fires throughout the study area.

23. **Unique Recreational Activities:** The SNF has unique hydrological features that provide a unique recreational activity. For example, Grasshopper Glacier is named for the millions of grasshopper that are entombed in the ice. Also, Sinks Canyon State Park features the Middle Fork of the Popo Agie River disappearing into a wall of porous limestone, and then reappearing about a half mile later.

Appendix D: Focus Group Rules

Focus Group Rules/Information

- Be respectful – We are here to discuss the full range of water-based benefits provided by the Shoshone National Forest. We are NOT here to discuss which benefits are the most important, or how the water resources in the Wind/Bighorn River should be allocated. Therefore, everybody has the right to express their perspectives and ideas, and they should not feel that they will be chastised for expressing themselves.

- Confidentiality – Any information gathered during this focus group will be attributed to the group as a whole. In other words, I will not be assigning ownership of any comment to any person in particular. In my thesis I will describe the make-up of the focus groups by mentioning the various organizations and interests represented. This will be done to stress the wide variety of stakeholder interests accounted for.

- Discussion Format - For the question about water-based ecosystem services every participant will write down three answers. We will then go around the room and hear one benefit from each person. We will do our best to articulate the benefit as we go around, and during this time it will be an open floor for anyone to speak.

Appendix E: Demographic Survey

1.) What is your gender?
- ☐ Male
- ☐ Female

2.) What is your age?

Age: _________ (years)

3.) Do you have children? (Check all that apply)
- ☐ No Children
- ☐ Children under 18 living with you
- ☐ Children 18 or over living with you
- ☐ Children under 18 not living with you
- ☐ Children 18 or over not living with you

4.) **What is the zip code of your primary residence?**

Zip Code: ___________________

→ How long have you lived at this zip code? ____________ (years)

5.) Which of the following best describes your primary residence?
- ☐ Apartment, condominium, or townhouse
- ☐ Home on 1 acre or less
- ☐ Home on 1-10 acres
- ☐ Home on greater than 10 acres

6.) How do you describe yourself? (Check all that apply)
- ☐ American Indian or Alaska Native (Tribe Affiliation) → ____________________
- ☐ Asian
- ☐ Black or African American
- ☐ Other ___________________________
- ☐ Hispanic or Latino
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White or Caucasian

7.) What is the highest level of education you have achieved? (Check only one)
- ☐ Less than high school diploma/GED
- ☐ High school diploma or GED
- ☐ Associate's degree
- ☐ Bachelor's degree
- ☐ Master's degree
- ☐ Doctorate degree (Ph.D or Ed. D.)
- ☐ Professional degree (MD, DDS, JD, etc.)

8.) Which of the following best describes your current work status? (Check all that apply)
- ☐ Employed full or part time
- ☐ Active-duty military personnel
- ☐ Student
- ☐ Homemaker
- ☐ Unemployed and not looking for work
- ☐ Unemployed and looking for work
- ☐ Retired
- ☐ Other (please explain) ______________

(Turn Over Please)

9.) Are you or have you been employed in any of the following professions? (Check all that apply)

- ☐ Agriculture
- ☐ Ranching
- ☐ Wildlife
- ☐ Fisheries
- ☐ Mining
- ☐ Hydrology
- ☐ Municipal Services
- ☐ Guest Ranching
- ☐ Natural Resource Management
- ☐ Natural Resource Science
- ☐ Aquaculture
- ☐ Sports, Recreation, and Leisure
- ☐ Education
- ☐ Hydropower
- ☐ Oil and Gas Extraction
- ☐ Industrial Manufacturing Production
- ☐ I am not employed in any of these professions (If checked, skip to question 11)

10.) Do/did you or your employers draw water from any of the following sources to facilitate the profession(s) you indicated in Question 9? (Check all that apply)

- ☐ Groundwater
- ☐ Municipal water
- ☐ Surface water (which body of water) → ____________
- ☐ Do not know
- ☐ No water drawn to facilitate the profession checked in previous question

11.) Which of the following water sources supplies your household with water for drinking, washing, and other in-house uses? (Check all that apply)

- ☐ Municipal water
- ☐ Groundwater
- ☐ Surface water
- ☐ Do not know
- ☐ Truck delivered water
- ☐ Other (please explain) ____________

12.) Are you or have you been a member/employee of any of the following types of organizations? (Check all that apply)

- ☐ Tribal Land Management
- ☐ State Land Management
- ☐ Federal Land Management
- ☐ County/Local Land Management
- ☐ Irrigation
- ☐ Hunting
- ☐ Fishing
- ☐ Environmental
- ☐ Non-Motorized Recreation
- ☐ Motorized Recreation
- ☐ No, I have never belonged to any of these types of organizations

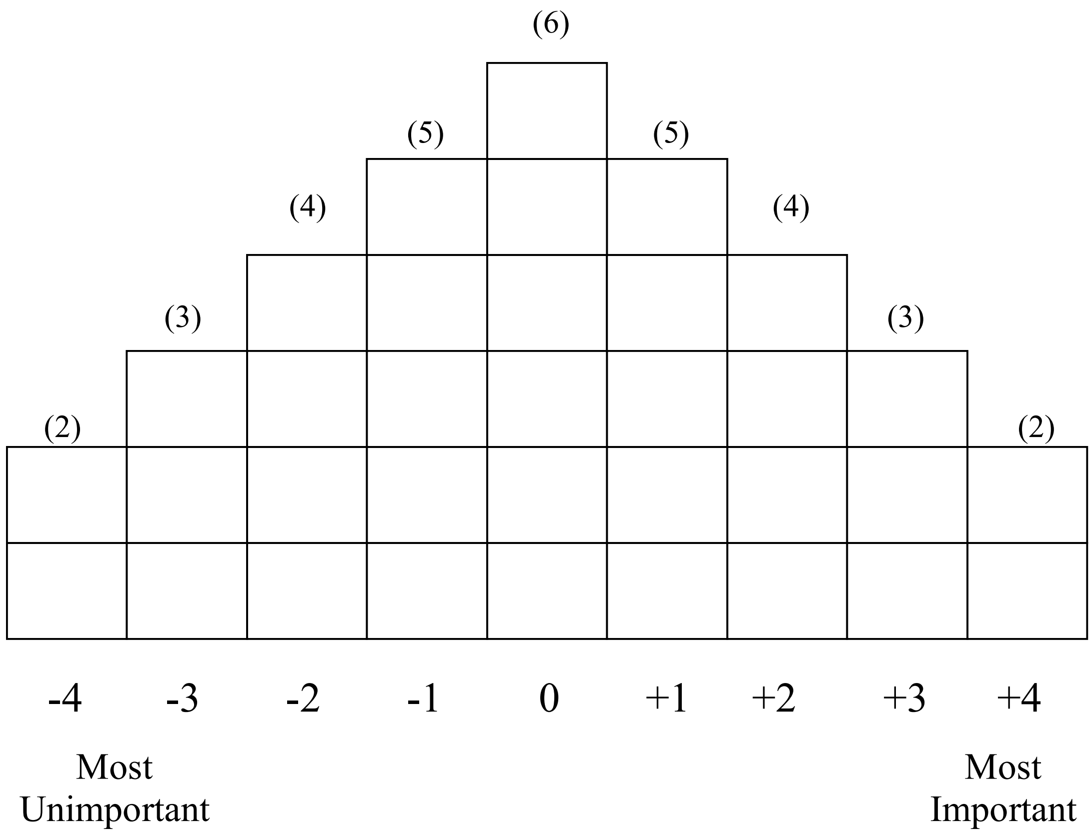
13.) What kinds of outdoor recreation do you participate in? (Check all that apply)

- ☐ Golf
- ☐ Field Sports (e.g. baseball, football)
- ☐ Snowmobiling
- ☐ Ice-climbing
- ☐ Non-motorized snowsports
- ☐ Waterfowl hunting
- ☐ Big game hunting
- ☐ Wildlife viewing
- ☐ Hiking
- ☐ Camping
- ☐ Lake/Reservoir fishing
- ☐ River fishing
- ☐ Whitewater recreation
- ☐ Scenic river recreation (e.g. flatwater boating)
- ☐ Motorboating/Personal Watercraft (e.g. tubing, water skiing)
- ☐ Other (please explain) ____________________________

14.) How many times have you participated in ice/snow/water-based recreation, sports, and leisure in the study area in the last 12 months?

- ☐ None
- ☐ 1-5 times
- ☐ 6-10 times
- ☐ 11-15 times
- ☐ 16-20 times
- ☐ Over 20 times

Appendix F: Q-board with instructions given to each participant during the data collection process



Please rank the statements on the cards from most important to most unimportant from your perspective. Each statement represents a water-based ecosystem service derived from the Shoshone National Forest.

Appendix G: Z-scores (factor scores) and corresponding ranks for each water-based ecosystem service by perspective taken from PQMethod output

No.	Statement	Perspective							
		Environmental		Agricultural		Native American		Recreation	
1	Water quality	1.90	1	1.15	5	1.65	2	-0.65	23
2	Preserving livelihoods, lifestyles, and landscapes	0.07	16	1.67	3	-0.21	21	1.10	6
3	Water for stock	-0.69	26	1.62	4	0.68	8	-0.03	16
4	Commercial irrigation	-0.78	28	2.25	1	0.29	19	0.66	11
5	Oil and natural gas extraction, and mining	-1.94	34	-0.08	19	-0.34	22	-0.18	20
6	Commercial water-based recreation	-0.59	25	-0.63	26	-1.58	32	1.03	8
7	Education, management and science	0.71	10	-0.48	24	0.44	15	-1.31	33
8	Household/municipal water	0.72	9	1.97	2	1.53	3	1.92	1
9	Hydropower	-1.49	31	0.76	8	0.78	6	-0.13	19
10	Land-based hunting	-0.24	20	-0.01	18	0.42	17	1.10	7
11	Non-motorized ice and snow based recreation	-0.05	18	-0.45	22	-1.67	33	0.82	10
12	River recreation	0.69	11	0.02	15	-1.48	31	1.36	5
13	Fighting forest fires	-0.84	29	-0.11	20	0.54	14	-1.23	32
14	River-based fishing	0.54	14	0.37	9	-0.45	24	1.52	2
15	Conservation of rare plant species	0.74	8	-0.68	27	0.57	13	-0.98	28
16	Conservation of keystone (critical) species	1.56	3	0.02	16	0.62	11	-0.65	24
17	Manufacturing and industrial	-1.90	33	-0.18	21	-0.36	23	-1.14	30
18	Nutrient cycling and sediment transport	0.96	5	0.15	11	0.11	20	-0.87	26
19	Physically and mentally challenging recreation	-0.29	21	-1.20	31	-0.90	27	-0.09	17
20	Personal irrigation	-0.70	27	0.93	7	0.58	12	-0.50	22
21	Motorized ice and snow based recreation	-1.65	32	-0.69	28	-1.91	34	1.37	4
22	Lake, reservoir, and river-based hunting	-0.49	23	-0.92	29	-0.85	26	0.27	13
23	Lake/reservoir recreation	-0.33	22	0.12	12	-1.36	29	1.50	3
24	Recreation/leisure activities done near water	0.55	13	0.01	17	-1.26	28	-0.10	18
25	Supporting of commercial land-based recreation	-1.21	30	-0.49	25	-1.39	30	0.16	14
26	Native American cultural and spiritual values	-0.16	19	-1.69	33	1.69	1	-1.18	31
27	Biodiversity conservation	1.61	2	-0.47	23	0.43	16	-0.77	25
28	Glacier-based services	0.20	15	-1.05	30	0.65	10	-0.44	21
29	Natural flood control	0.85	6	0.33	10	0.69	7	-1.03	29
30	Lake/reservoir fishing	0.02	17	0.12	13	-0.71	25	0.88	9
31	In-stream flow	1.38	4	0.11	14	0.93	4	0.05	15
32	Gradual discharge of stored water	0.78	7	0.95	6	0.67	9	-0.97	27
33	Non-Native American cultural and spiritual values	-0.50	24	-2.10	34	0.81	5	-1.93	34
34	Inspirational and aesthetic values	0.56	12	-1.32	32	0.41	18	0.45	12

Appendix H: Interview Transcriptions

The transcriptions below are from the 96 interviews completed between February 12, 2012 and March 14, 2012. The investigator engaged in the drivers discussion with each participant with regard to their two 'most important' water-based ecosystem services. For the most part, the following transcriptions for each respondent are presented with five bullet points for each of their two 'most important' water-based ecosystem services. The five bullet points represent the following:

1. The first bullet point is the participant's response to the following question from the investigator: "what factors or influences do you see as impacting, either positively or negatively, your ability to receive your two 'important ecosystem' services?" This question was asked with regard to their two 'most important' ecosystem services before the climate change trends (bullets 2-5) were presented.
2. The second bullet point is the participant's response to the earlier-runoff trend.
3. The third bullet point is the participant's response to the trend for more frost-free days.
4. The fourth bullet point is the participant's response to the trend for rapidly melting glaciers.
5. The fifth bullet point is the participant's response to the trend for increasing minimum temperatures.

The specific questions related to bullet points 2-5 can be found in Section 5.3. The above description of the interview transcriptions apply *for the most part* because, even though the interviews were generally similar, there were times when participants would reply to a question in a way that changed the flow of the interview. For example, the interview for Participant 5 presents the five bullet points for both ecosystem services at the same time because the Participant felt that the two ecosystem services were similar enough that his answer would apply to both. There are also certain interviews that do not have five bullet points for both ecosystem services. In these cases the participant usually stated that the four trends would, or would not, impact their ability to receive their 'most important' ecosystem service before the investigator could get through all of them.

Participant #1
Water Quality

- "So from the Forest, all the water coming off the forest. When I am thinking water quality, I am thinking drinking water. The day in day out usage. Positively, the way the forest service is going to manage the land. What they would allow the ranchers. How much would they be willing to regulate people in the area for environmental factors, like rancher's waste and beyond that other industry in the area. All of the mining and stuff. How strict are they? That would impact it positively or negatively, that is number one. What the laws are and regulations that people are going to have to follow. Businesses and recreation out there rallying on snowmobiles."
- Earlier runoff: "If it kept running off earlier then it could run out in the long run. The balance of the system would be disturbed, and there would be negative impacts and the water quality would go down. You would have land degradation and drought, which would eventually impact water quality."
- More frost-free days: "Yes, if you are having more frost free days then you are having a longer growing season and you are putting more stress on the resource. You could have poorer water quality down the road."
- Rapidly melting glaciers: "Yes, that is a huge fresh water store that will eventually run out. That is the same as Kilimanjaro, all of those glaciers feed whole communities. Yea, that is huge a stock of fresh water. Once that is gone you are not going to get it back."
- Increasing minimum temperatures: "I am picturing the decertification of the Sahara. The climate keeps going up uncontrollably, and nature will not be able to rebound and change with it fast enough. Water quality will get impacted negatively. The more it burns, the more it kills off the trees. Hotter and drier. It is all impacted."

Preserving lifestyles, livelihoods, and landscapes

- "I am not super familiar with that area. I am imagining it is kinda that heart of Wyoming. I am thinking ranch industry, cattle, the oil industry, natural gas drilling, recreation to some degree. Those people are relying on the water in that area to supply their whole livelihood. The water resource is so precious. How the federal government will regulate. Management. Regulations, or whatever governing body is going to do. Even local."
- Earlier runoff: "Yeah it is stressing that resource. I am picturing the huge irrigation arms. If they are running out sooner then that is a problem."
- More frost-free days: "yeah more stress on the resource."

- Rapidly melting glaciers; "yeah it hasn't been dated and studied well enough to how we would respond to these things. I guess the dust bowl would be something, but they didn't hard core analyze it in a way we would today. It is gonna impact us in a way that we haven't necessarily seen before, so it will be hard to tell how it will all work."

Participant #2
Water Quality

- "Probably just land use, and how we manage forest fires, timber harvests, road construction. All those things are going to impact water quality. How we manage recreation, road building, construction, yea just land use in general."
- Earlier runoff: "If you get a lot of flash flooding, you do not have time to get a lot of that surface runoff. You probably have a lot more sediment transport, a lot let water becoming ground water and more flushing out of the system. I think that could be a negative thing of having an earlier peak runoff. Those bigger higher magnitude floods. That has a lot to do with natural flood control. In order to have water quality, you have to have the forests, the soil structure and the forest structure. That is not really gonna be impacted by timing."
- More frost-free days: "I don't know how it would."
- Rapidly melting glaciers: "Yeah, I could see that. I guess water quality is derived from how you use the land, and from how the land filters and processes the water. The glaciers are going to impact the volume the flow, but as far as how that impacts water quality. As long as the system stays intact and the water is flowing through it."
- Increasing minimum temperatures: "I don't know, I don't think so."

Natural Flood Control (Unprompted mention of climate change)

- "Land use definitely for natural flood control. How you develop the Shoshone is a big thing. Definitely global warming. They are calling for more intense short duration storms, which could have an impact on the ability of attenuation of water. Positively impacting natural flood control, I think positive and a negative I think we are shifting a lot more towards preservation of the forest. A lot less use of the forest. An overly utilized forest I think you are going to get positives because you are going to get better flood control as a result of better soil structure and more evapotranspiration of trees. You also get negatives if you do not harvest the forest, because too much is just kept up in the mountains instead of being released out."
- Earlier runoff: "It is just the magnitude of the earlier runoff. The ecosystem does a real good job of natural flood control as a way that it evolved with natural weather patterns. But if we start altering weather patterns and we get, not necessarily earlier runoff but a higher magnitude in runoff then it could impact this service."
- More frost-free days: "That could impact soil structure which could impact percolation and stuff like that. That could decrease peak flows, I do not know. Maybe."
- Rapidly melting glaciers: "If they stop contributing to that base flow."
- Increasing minimum temperatures: "Yeah definitely. If you are keeping less in the watershed, because if you get more rain instead of snow then it will impact flood control. And the ability of the watershed to have flood control. If you mess the ratios of snow to rain."

Participant #3

Lake/Reservoir recreation

- "Land management, forest management, like how the water quality might suffer after a fire and how it might affect fish in that environment. All the debris that comes down and fills reservoirs. I am a sailor, and so I do sailing and sailboarding out on Buffalo Bill. My season is impacted by debris floating down, like after the Gunbarrel fire. There are other factors, as far as restrictions. As far as the fishing opportunities, and the restrictions that are in place in order to, depending on your perspective, either preserve the fishery or enhance it, or restrict it and manage it. As far as lake and reservoir recreation, that is one set of comments about one particular reservoir that receives in a major area, there are thousands of lakes in this area that are not affected by factors like that. That are left for experiences such as solitude, and hiking and camping, which are of great value to me and knowing that places like that are there is really important. In that respect, having access to those areas is really important. I appreciate the opportunity to gain access to these areas, I have also lived in other areas where the national forest is bound by private property and access routes into the forest are very limited. That is one nice thing about here."
- Earlier runoff: "It does affect it. One thing that we have struggled with here at Buffalo Bill is the irrigation offset. When runoff and irrigation are out of sync, then we end up pushing a lot of water down the river and it is not put to beneficial use. So the earlier that the runoff occurs, the more water we lose. Ideally, I would like that runoff occur at the same time that we are irrigating our fields, and that way we could maximize that benefit. I do not know how it affects my ability to enjoy the recreation. For example, last year in preparation for a large runoff the Bureau drew the reservoir level down 75 feet or some incredible volume in order to make room for the expected runoff. I couldn't sail out there, I could gain access to the boat ramps. I do not know if it had an impact on the fishery, because you subject the fish to a lot of stress with the reduced volume and the turbulence."
- More frost-free days: "Yeah, that would seem to increase turbidity."
- Rapidly melting glaciers: "Yeah, especially in the smaller isolated drainages and reservoirs in the high country. Once those glaciers, once that supply of ice melt diminishes then some of those lakes will not be able to sustain themselves or a fish population."
- Increasing minimum temperatures: "That certainly would, assuming that. All these questions are geared towards climate change, and being a geologist I do subscribe to the concept of climate change, but yet at the same time one looks at a broader period of time or a longer period of time than the 80s till now. Yeah, if we continue to have an increase of 2.6 degrees F per decade, and glaciers diminish to the point that they come extinct then yeah that will certainly impact my ability to enjoy lake/reservoir recreation. But as me that question in 20 years when we are talking about the resurgence of the glaciers, and what are we going to do about the abundance of ice. We are gonna pump more carbon dioxide."

Water Quality

- Earlier runoff: "I think that one thing that might happen is there is a lot of natural filtration that needs to occur in the water as it comes from snowmelt and sheetwash over the land before entering the riparian system. And so, say for example that you do not have a robust vegetative strip along that river then you are getting sediment laden water going directly into the river. And so, therefore, if the vegetative filter is not mature enough to sustain or perform that function then you certainly are going to affect your water quality. In addition to that there is going to be dumping in nutrient from cattle or wildlife pathogens, and so if we do not have a mature filter strip then that would affect water quality."

- More frost-free days: "If we are getting more and more frost free days that might imply that we would have a mature filter strip earlier in the season and perhaps later in the season too. In that regard, perhaps the system can maintain itself and that function."
- Rapidly melting glaciers: "Well yeah again, how quickly water sheds off that system makes a big difference. Also the ability of that water to be used in the forest to support different habitats on the way down makes a big difference, so you have more diversity and that slows the movement of water over the landscape. The slower it moves over the landscape the less erosion occurs, and the more filtration occurs and the more benefits to the creatures including me."
- Increasing minimum temperatures: "An average increase in temperature of 2.6 degrees F per decade would certainly affect water quality and the fact that we would have a host of new organisms living in the water that would upset the current species that live there and have learned to exist in this excellent quality water. I would think that also that would introduce additional complications as far as mans use of beneficial use of that water, because additions filtrations and processes would have to be applied to that good tasting water that we enjoy now with minimal treatment."

Participant #4
Commercial Irrigation

- "As far as negative impact I would say regulation. We are not against regulation by any means but if there is no balance then other interests tend to take the forefront. You know, farmers and irrigators are just working people; they don't get too involved in government, unless it is absolutely necessary and a lot of times things are imposed on them. They should get more involved, but they don't and a lot of times it is too late to do anything about it. These guys want to be involved in conservations; they are involved in it and it is to everybody's benefit to have clean water and to have all the other benefits that you have but sometimes those things tend to outweigh or overcome the interest of those that are making their livelihood with water, and it is seen as kind of a bad thing. If it goes unchecked then down the road you end up with so many regulations that you cannot afford to keep farming. That is one of the main concerns that make their living out here have. As far as a positive impact, having a consistent resource that is not depleted and keeping that balance is beneficial to everyone. You cannot use the river just for irrigation. It is to everyones benefit to work together."
- "I have not noticed an earlier runoff; to me it is just a function of the weather. I do not know that there is conclusive evidence that we have a long term warming trend. It seems to be cyclical. I think it is better when it is a little more gradual so the Bureau can handle it. When it all comes at once it is an issue because they have to get rid of it. Water availability it is not an issue because of storage."
- "If glaciers continue to melt then it will be a real problem for irrigation."

Hydropower

- "Hydropower is essential to this area. We would not have anyone here if it were not for hydropower, because we would not have the dam there. If it were not for the dam then there wouldn't be any communities here at all, and hydropower is just an element of that. It is something that is essential to this area, and it is were we get all of our power from and it is a green energy source. Yeah it uses a dam, but that is one of the benefits of a dam. We are trying to incorporate more hydro, but we are trying to use conveyances that are already in place. We are trying to put a small lowhead hydroplant on a canal drop. That is utilizing the resource while we have it in our irrigation system, utilizing it, repurposing it. We are using water that has already been diverted, we are not putting anything else in the river. For us it generates revenue that we otherwise would have to generate through taxes. It is a huge benefit to irrigation districts if they can get it in place. It helps us pay for the replacement and repair of our infrastructure without having to tax land owners."

Participant #5
Commercial irrigation and water for stock (Unprompted mention of climate change)

- "Future influences that could affect the delivery of water for agriculture. Future demand on water that would exceed the availability could negatively influence the delivery of water for agriculture. It is important that everyone keep on their mind that our irrigation projects exist here is because that reservoir, Buffalo Bill Reservoir, was built for the delivery of irrigation water and for agriculture. It is being managed by federal agencies and it is being managed by people who could either positively or negatively affect the delivery of that water to farms. Climate change, reduced snowpack could create a reduction in the availability of water. How the forest is managed would probably not affect it too much. The amount of snow that lands on the mountains would melt sometime during the summer and it is going to end up in that Reservoir. The delivery of that water is managed by federal agencies, and some state management is involved too. That will affect the delivery of water for the farms probably more than anything in our lifetime."
- Earlier runoff: "not with the storage that we have in the reservoir, and the ability to control that runoff with the dam."
- More frost-free days: "Potentially if we see an increase in growing days, then we see an increase in vegetation on the forest, because the vegetation would use more water that might typically run off. However, with the forest fires of 88 and the loss of a lot of timber there is actually more water coming off than prior to that. And the water is probably coming off earlier because the ground is no longer as shaded as it was before the fires, so the snow is melting quicker because the sun hits it quicker."
- Rapidly melting glaciers: "Ultimately if they continue to recede there would potentially be less water in the drainage for agriculture and other uses. I think the last couple winters prior to this winter some of those glaciers grew a little bit."
- Increasing minimum temperatures: "Assuming that information is accurate, 2.6 degrees in ten years is a pretty big change. It would certainly influence the timing of snowmelt, and it could change the timing of runoff. As long as precipitation does not decrease, I do not see that increase in temperature having a huge impact. But if that increase in temperature is accompanied by a decrease in precipitation then it would have a huge impact."

Participant #6
Least important were cultural and spiritual values (both non-native and native)

- "Basically my spiritual belief is not related to land, it is biblical, so cultural, spiritual and religious purpose. My basic religious beliefs to not include any activities outside of the church buildings, I do not do any spiritual outside activities."

Most Important
Water Quality

- "Basically vegetation control to stop the runoff into the streams. Whether it is controlled, controlling natural fires to the extent that it does not totally devastate everything all at once. Or whether it is prescribed fire for control to compensate basically for the loss of trees, mainly, from the beetle kill. Basically maintaining a good vegetative cover to stop the flow of soil and the contamination of the rivers from erosion."
- "Because of Buffalo Bill Reservoir I would say no for number 1. I think the Reservoir would contain the flow, and therefore you could manage the release of it."
- "Really frost free days would probably have minimal effect, although depending on the vegetation change because of frost-free days there may be some. Again, looking at it from the standpoint of erosion I do not see that many more frost-free days would be necessarily detrimental to receiving the quality water that I want."
- "As far as glacial runoff, we are picking one study out of all of them. I do not know that I would agree with this study, but I would say that I probably, most of the water that I get comes from yearly snowfall, so I would not put the glacial part involved in it that much."
- "Again, because of Buffalo Bill Reservoir I do not think that if there is that much, I do not agree with the studies, and you said that we are not going to discuss that and that is fine. I would say that Participant #4 would not necessarily affect."

Household/Municipal Water

- "Same kind of thing except that maybe more so to the point as to whether, in my case, most of the water that I drink is out of the Shoshone Municipal water system. Therefore, having a good clean source of water, even though it can be cleaned up within the system and the processing of the water, it is just the fact that the cleaner it is before it goes into the plant the better I feel about it regardless of the total outcome. And cheap because it does not cost as much to clean up the water, and it will be cheaper to get.
- Both of his most important apply the same to questions 1-4.

Participant #7
Preserving Livelihoods, Lifestyles and Landscapes

- "Great question. We cannot have any more dams I guess. So we are already set up with a pretty good infrastructure for using the water here, in our location. I guess development would be a factor contributing to the ability to not get those things. Natural disasters, I guess, I cannot think of anything else. Like floods, or catastrophic events to the watershed or some sort. A fire, followed by sediment travel. That could negatively affect our ability to use those."
- Earlier runoff: "Yeah I suppose it probably could, it affects the time in which you can get your water and make it usable. I am thinking for stock and crops, I do not think that is going to make a difference."
- More frost-free days: "Probably, it is all going to affect the watersheds ability to charge itself, I guess could be something that you could see with that. You could also see a shift, if it is going to be a major change, you could see a shift in plant communities which could affect bank stabilization and things like that."

- Rapidly melting glaciers: "Yeah it could, glaciers are a water storage type of thing, so if we don't have those then that is going to affect runoff and water quality. So yeah I think that could affect this card."
- Increasing minimum temperatures: "Yeah it could, just like a lot of the other things. It is really hard to say especially with small changes like that. If it continues it could change a lot of changes in places that you wouldn't even think about. It could trickle down and change the way the watershed functions and the way that we preserve our livelihoods, lifestyles and landscapes."

Household/Municipal Water

- "We are going to keep having our water storage, you know the dams, especially the Buffalo Bill dam for our household/municipal water and then the water pipeline infrastructure. So yeah the same things as before, it is going to have to be big environmental changes or some sort of development would change our water requirements making it probably more, so affecting everyone else, but I do not know."
- Earlier runoff: "Yeah that is gong to have an affect on the reservoirs and containing the water and stuff, so there is a balancing act between letting the water runoff from the reservoirs and retaining enough to keep to use all year round. I guess that could change if the runoff date was earlier, or what have you."
- More frost-free days: "Probably the same kind of thing, it is going to change how the watershed functions, so it could affect how we get our water from it."
- Rapidly melting glaciers: "Glaciers is storage, so yeah"
- Increasing minimum temperatures: "Temp is same too. That is why I chose these as important. We have to have water to live and it is just the same for we have to have water to drink, water our livestock, and keep our farms going, whatever that may be."

Participant #8

Conservation of keystone species (Unprompted mention of climate change)

- "If the climate continues to warm then the habitat availability for Yellowstone Cutthroat trout will be limited, and it is already a threatened species."
- Earlier runoff: "Yeah I think that could."
- More frost-free days: "I think it would vary, I think it would be positive affect to some species, and negative to some. Or they may just move their population to a different place."
- Rapidly melting glaciers: "I do not know, or understand that much about it, but I would assume that it would."
- Increasing minimum temperatures: "It would definitely affect them, either it could be ways to mitigate that like introducing some species to some places, higher elevations where they currently don't have a population. It is really hard to know what the affect would be."

Preserving livelihoods, lifestyles and landscapes

- "We are talking if the climate is changing. I guess a big one could be agriculture, the local farms. The timing of them getting their water, and with ranches they depend on stock tanks and things that are pretty spread out. I am not that familiar with how much

impact that could have. Just on the availability on grouse and things for grazing, if we go into more of a drought period that could be a problem."
- More frost-free days: "It could enhance grazing, and it could be good for the forage and the grasses. It could increase the growing period, but I am sure that the crops are currently growing are pretty much in tune with the current climate regime, but maybe we will start growing grapes or something like that."
- Rapidly melting glaciers: "I guess it could indirectly if it affected some wildlife habitat, so that it could affect people that do outfitting and guiding for hunting, ice climbing."
- Increasing minimum temperatures: "I think it could have both positive and negative. Obviously winter sports might not be as great, but summer sports might be enhanced. Longer tourist season for the town."

Participant #9
Water Quality (Unprompted mention of climate change)

- "I think in terms of actually receiving it, what I look at is an area that is predominately undisturbed. There is a fair amount of our area that is pristine, so that would help me to receive it. In terms of not receiving it, I guess I think of things like changing climate that may impact that. Water regimes in particular associated with changing climate, how we are receiving our precipitation. I think a lot about atmospheric discharges, deposition of additional sulfur from industry, some of the air quality issues that then impact water quality changes. For example, we have our high lakes study area and you look at so many impacts that may be occurring from industry in terms of changing the water quality in these very very pristine areas, which then translates downstream. So we are changing our ph, our sulfur sulfate kinds of concentrations, habitat quality things like that. So those are the kinds of things that influence it, I guess there is also some minor impacts on water quality, and I mean minor just in that there is not as much human presence in these areas. So things like recreation with horses and packing, and where we are keeping our stock in these areas that potentially are providing really phenomenal water quality. Or the potential to provide, there are obviously some natural influences that may deteriorate it that are geologically driven. I guess with the water quality that is where I am coming from.
- Earlier runoff: "yes, basically I think that the changes in runoff when it essentially comes back down to low flow volumes, so what are we having for low flows later in the summer. If we are getting our peak flows earlier in the year, and I think it is also complicated by the fact that we will perhaps be changing the type of precipitation that we are getting, so not only are we going to get earlier runoff but there maybe spikes at different points during the year that we be more rain dominated rather than snow dominated which is going to probably change sediment loading and things like that. I think they add up for that."
- More frost-free days: "Yes, just in the sense again from the kind of shifting climate. If we are getting warmer days, then that is an implication that perhaps the type of precipitation we are going to be getting is going to change."
- Rapidly melting glaciers: "I think that certainly changes the storage component of it. What we have for high quality."
- Increasing minimum temperatures: "I keep going back to the same reasons, when you are thinking about rain vs. snow when it comes, how often it comes. Timing throughout the year, we are going to get more of this in the winter vs. summer."

Gradual discharge of stored water

- "I guess I am thinking snowpack, how much snow are we getting. The Shoshone holds a tremendous amount of snow, and then you have that kind of slow release. I think in part the huge factor that we have with this is the type of geology we have, with some areas are going to be more conducive to holding water and storing it. Whereas other are going to be prone to fast runoff. So snowpack for sure, and then again how much rain are we getting to drive the melt and the timing that is happening. Of course with the warmer temperature drying up some of these wetland areas that are storage components, in perhaps areas like the Northfork or the Southfork where the geology is such that you just don't have a tremendous amount of storage to begin with. So again, temperature driven type of precipitation driven, climate."

Participant #10
Water for Stock

- "I chose that one because locally if you do not have stock, if there is not water for stock locally then people would be forced to look outside this area or region for stock. So it would drive prices up, more local agriculture and farming. So you would have to find stock outside of the SNF area, it would put people out."
- "Climate definitely affects it, but it is not necessarily warmer temps but it could be the amount of rain or snowfall. It could be the colder temperatures that also affect in a good way as well. Snowfall rain, just the natural cyclical."

Commercial Irrigation

- "Pretty similar, especially because it is a farming community Powell is and Cody and in between. I would guess in the region that you are studying there would be a lot of it. It would be extreme if they didn't have the water. Local foods couldn't be produce, and we would have to go elsewhere for that."

Participant #11
River Recreation

- "Well we always worry about snowpack, last year was unbelievable close to the end of June and I looked on the government access on snowpack and we were 8837 percent of normal because it kept snowing and raining when it usually melting. We kept getting more and more. It was 30 some feet at Sylvan Pass, and we couldn't get in the park most of the time. I also worry about the forest fires, we see a lot of chocolate water coming down after a forest fire. When the water starts going down it crystals up and it is just so beautiful, you can see the trout in there. People love that, but they do like the higher water so it is better flow and more exciting. We worry about water quality, and we worry about water. There are years, back in 76 when I worked for Kit Cody the water was so low that we had to get out and make lanes through the river so we wouldn't hit rocks, and move rocks. It was just a float there wasn't any whitewater at all. We worry about the volume of water, and how clean it is. I was in South America looking for water to float, the Bogata River was so polluted by waterfalls the foam was a foot and half thick. I truly believe that if you floated that river, ten years after you would have cancer. We are so blessed that we live here that the water is so, I drink water out of the river all the time. I did get giardia one time, up at sunlight basin. Mainly it is the quality of water, and we worry about if we get water. Right now we are 83 percent of normal and Cody area is 90 percent of normal.

- Earlier runoff: "I am not yet sold that the humans, I know that we have to affect our climate in some ways. Like I said, I had a degree in geography and we studied the four glacier periods, the Kansas, Nebraska, Illinois and Wisconsin glacier and we are supposed to be in an interglacier period now. I know when I was a kid in northern Wisconsin we froze our ass off, it was cold and snowy every winter. Here it is not so bad, and they tell me that years ago here it was cold and snowy. It has changed no doubt about it, and anybody that says it hasn't changed they are blowing smoke, but I don't know how much we affect it. I don't know how we can control it any better, and I do worry about climate change. Last year all of May and first have of June we were raining and cold here and I have never seen a season like it. It was wet and cold, we had a fairly good year, third best year people wise. It was colder than hell."
- More frost-free days: "We have had cooler summers the last couple summers, it is hard to see that. I remember when I was in college coming out here, we would only have a couple rainy days. It was hot and dry, and we would have some showers come in around 2 o'clock. Thinkgs have changed, I know we had out by the horses, there was an 8 year period that we had a drought and we were worried about losing horses. Dry creek always had water because Marathon Oil is pushing water through there, that was even drying up at times. So we were very worried about that, but last year we had the best grass ever because it was such a wet spring."

Water quality

- "I see water quality change on our Northfork due to the 88 when we had the fires. From that point on we seen the river in the spring, there are years that it is just like chocolate coming down there because it burned off all that grass that held that soil and that is bad. It is just like the bark beetle, and they have said that we haven't had the severe winters. I have read that we need 3 weeks of 30 and below weather to kill off the bark beetle. Being at the AOA a month a and a half ago, they showed from 1970 till now the bark beetle kill. Our forests are just devastated, they are over half dead. That is what causes your forest fires, it is all this dead timber and that does affect our water quality down here. There is no doubt about it."

Participant #12
Natural Flood Control

- "I am just a big supported of conserving riparian zones, and stuff like that. So the natural flood control, as opposed to how they manage the Reservoir here would be more important to me because they do not manage it well."
- Earlier runoff: "yes"
- More frost-free days: "I am really ignorant about that, but I do not think so."
- Rapidly melting glaciers: "I believe so."
- Increasing minimum temperatures: "Yes."

Biodiversity Conservation

- "A negative impact by anything over usage or flooding or whatever, I mean biodiversity is the key to any healthy environment anywhere and these fisheries are very fragile to like the Yellowstone Cutthroat which is a native species here. Once biodiversity is gone, it is pretty much shot. Management, and the flooding, and also just making sure that our riparian zones are intact."
- All questions: "Yes to all four, we are going to have to learn how to deal with that."

Participant #13
In-stream flow

- "It is really difficult to, basically I am referring to the tailwater here, which we have control over more or less. We have seen basically that the people that control in-stream flow control whether we have good fishing or not, good aquatic insect hatches or not, whether we have a healthy river at all. They really do not care, so basically at this point I see us having really bad in-stream flows, inconsistent from year to year. Very poorly managed, short sighted and made for irrigation of agricultural goods and services and that is it. They care nothing about anything else beside ag, I see us having a nightmare here in the next decade with that issue, but when it is working properly and we have a few good years of water in a row and they are not having to cut it back in the winter we have a lot of recreational opportunities for a lot of people. Whether it is fisherman coming in the winter to fish the hatches in the winter, which are awesome around here, and you have to have enough water to keep the habitat under the water healthy for those bugs. They cant have the giant floods and releases because it washed them all away, it washes their food base away. I look at in-stream flow as our biggest nightmare around here, and when we have enough of it my business thrives and the whitewater people love it. All businesses thrives when the lower Shoshone is doing well, when it is not we see a sharp drop in the wintertime use and almost no use for the whitewater people. It is management, and it all goes to the guys down in Casper and they keep telling us they do not have any responsibility for the fish and game along that corridor."
- Earlier runoff: "I do believe that we affect the earth, I mean you know big time. Absolutely, well and it already has and I do not know if it is due to climate change whatever, I am sure natural or man made the climate is changing. We are seeing the cutthroats are spawning earlier and earlier. I think that has some adverse affects, and while the temperature can be warmer, they can get extremely cold and from what I have read it can kill the eggs and make it so they cant get fertilized. It already is affecting it, maybe not on a large level but we can see changes all over the place from exactly that problem. Also, the animals that depend on those runs. I don't think they are adjusting to it, I used to see coyotes fishing on the spawn and you do not see as many animals fishing it as much."
- More frost-free days: "Now the frost-free days, as far as I look it. The more frost-free days that we have on the shoulder seasons, it just means the quicker the water is going to warm up. It just means that it is warmer out there, and the water is going to warm up quicker and on low water years it will affect temperature. A lot of the time we find that at the end of August on a low water year we just start to get into the danger zone, and then the cool weather hits. Whereas if that is happening earlier then we could see it rise from 67 degrees and right on the edge of danger and deadly to 70. It could cut into not just the season, but also the spawning season and I think the temperatures are screwing that up. Right now we

have fish on the lower Shoshone spawning, and that never happened when I was a kid. We have also been seeing some weird things with the bug life, up in Yellowstone we saw golden stone hatch in October, which is supposed to happen in June. Really odd, and we had the guys at the University of Idaho identify the nymph. Those are supposed to be lined up at the end of winter when the cutthroats are skinny and hurting, those bugs hatch and save them from starving at that moment. They gain up to 70 percent of their weight in three weeks, and so if it doesn't coincide with the fish running up and spawning and being in those areas then they don't match and some of those fish maybe go hungry."

- Rapidly melting glaciers: "Glaciers melting is very bad because that keeps our rivers cool, and gives them that constant temperature and around here where we are so close to them it almost guarantees that we will not have die offs. It just keeps running in cool all summer, and even though it may not be as much now it is still some and it still makes a real difference."
- Increasing minimum temperatures: "Absolutely, once again it just goes right back to water temperature and trout, with the lack of water you are gonna get high water temps and with 2.6 degrees per decade and that would definitely cut off august and kill every fishing operation in the rocky mountains.

Water Quality

- "The second it hits ranch land the water quality starts to fall apart. And I grew up on a ranch and a farm, and they are not the stewards of our waterways or our land. That is one of the biggest misconceptions, and don't get me wrong I eat beef, but I want it off a feedlot, not grazing up in high mountain meadows for fuckin free. Wherever there is anything up in the high country water quality dips greatly, whether you go to the gold mine up at the head of the wood river which is a 100 years old and it is still poisoned up there and the fish still can live up there. Once it goes subterranean and pops back out then it is fine, but man can stick his finger in there and ruin it for 100, 200, 300 years just for the profit of a few people. Any that affects water quality, and this is our water, that is benefiting someone financially is bullshit. I believe that grazing in the high country should be a felony, and I know that we need hay for our cattle. As you get down on every river here, you see the change in aquatic insects and really the change in temperature is not there. It shouldn't be that change in insects, but you see all this stuff that makes the hay grow faster and it all washes into the river and it changes the ecosystem and all of the sudden the stone flys are small and they never achieve that full buff size that they do on the upper end. You see this covering on the rocks, some sort of moss that doesn't bode well for the amount of oxygen in the river. Just the cows pooping and peeing in the river and that running in their affects it the same. I would say the water quality, once you come off the forest drops about 70 percent due to ranching. The Clarks fork it is shocking, you go from terranarus califonica country that needs massive amounts of oxygen and pure water runs all the way out, and then the feed lots start and it is gone. You do not find wild cutthroats down there, and they are at a premium in that area. It is hard for them to find quality spawning area in that river. The water quality once you hit ranch land sucks."
- Earlier runoff: "Don't think that will affect water quality that much until later in the year, it will drop quicker in August and then you will have more of a concentration of stuff in the water."

- More frost-free days: “it will warm it up a bit, and take away a little of the benefits of the oxygen. Probably not too much.”
- Rapidly melting glaciers: “Glaciers melting is a big deal because it brings up water temp a lot.”
- Increasing minimum temperatures: “Same deal, water temps are up and that affects oxygen and water quality.”

Participant #14
Conservation of keystone species (Unprompted mention of climate change)

- “Well the positive is that I look at this and I see the whitebark pine is a critical food for grizzly bears, and I see beavers as really critical for watershed management. Cutthroat trout, we have a reputation around here for being a world class, if not world class then national, fishing destination and the cutthroat trout has a huge profile, and because of that if we lose one or more of those species it going to significantly alter the ecosystem. Management would affect any and all of them if they are mismanaged. Obviously water, ample water and the quality of water, climate change.”
- Earlier runoff: “I think slowly over a period of time it has got to.”
- More frost-free days: “Yes, I do.”
- Rapidly melting glaciers: “Yeah, there again I have to think that it would.”
- Increasing minimum temperatures: “Yeah.”

Water Quality

- “Definitely management, climate change, global warming or global cooling.”
- “Each one, yeah all of these will affect the quality of water.”

Participant #15
Conservation of keystone species (Unprompted mention of climate change)

- “Climate change is going to have a big impact on how these particular organisms will function in the ecosystem. We are already seeing a lot of impacts on whitebark pine, and the less water that we have the less water that will be available for Yellowstone cutthroat and other organisms. We are going to need the beaver to preserve what water we have, but I think climate change and I think we need to have more fire to clean up some of the bark beetle infestation. I think we need to let mother nature take care of the fire, and not do so much management to protect million dollar houses that we spend ten million dollars to try to save. Just let it burn and give them the money to rebuild it.
- Earlier runoff: “On a time scale vs a long scale we are not sure, there are a lot of things on climate change that has people skeptical. I have been working very closely on a climate change study, and I have been working with the USGS on temperature and flow gauges as a template for research on other watersheds. I am aware of all these things. Do I believe it all, no. I am still skeptical that it may just be a blip, but it doesn’t mean that I do not think we need to something with greenhouse gases.
- “If the trend continues, then it will impact these services. Some areas more than other, there are certain areas in the ecosystem that will not be as impacted, like the high areas may be impacted less than the lower areas. There actually areas from a fisheries perspective that may have areas that hold more fish, because right now they are too cold. A little climate

change may have some natural reproduction benefits. Right now they are too cold for incubation."

River-based fishing

- "I think the particular area of your interest has a lot of nice rivers, and I think the ability for us to use the resources we need to maintain a good healthy river environment. That is what I am in the business of doing, to provide the opportunity for people to fish and I think the river-based fishing opportunity is sinking. Gradually we are losing more of it across the country, it is in high demand and I think we out to protect it."

Participant #16
Water Quality

- "Things like the oil industry, with fracking going on. In my mind it is the kind of thing that eventually we will find that it is going to screw up the water. Land use, whether it is the timber industry, farming, agriculture definitely impact water. At the same time it is nice not to have a huge amount of industry impacting the snowmelt, for example low sulfur coal being burned where you have the acid rain fallout into the snow. So we do maintain a healthy watershed from the SNF into our water, those are the things that I worry are going to impact it and hopefully we will not take the easy way out and treat the resource with respect."
- Earlier runoff: "I do not know, I don't have a feeling on that one way or another."
- More frost-free days: "Potentially, if you have snowmelt sooner then it will not last as long."
- Rapidly melting glaciers: "yeah it would seem to me so, I think your water quality is going to go down."
- Increasing minimum temperatures: "yes, along those same lines. Just being able to hold the water longer it will impact the quality, and the domino impact there."

Conservation of keystone species

- "Again it is such a healthy place to track the snow and the water that we as a society take for granted of the quality of things that are up there, just natural healthy resources. That is one of the reasons that I live in this area, to get the clean water, to go up there and breath fresh air, and so I think those are all critical to species, from quality water comes quality everything else."
- Earlier runoff: "I think everything in that regard. There is always a domino affect, things always interreact, though I do not know what that would be. It would make sense, for example, wildlife being able migrate in and out of the mountains sooner. Does that have an impact on foliage, yes, I would say it would. Is that going to be a negative impact, I do not know."
- More frost-free days: "Potentially."
- Rapidly melting glaciers: "I would say it is going to be a negative impact on species."

Participant #17
Conservation of keystone species (Unprompted mention of climate change)

- "Well I think a couple things. We have been in drought quite a while here in the basin, so that is affecting some of the species. Also, climate change so I am thinking if things proceed with climate change the way some people think it will I think we will be in trouble, I think some of these species will be in trouble."

- Earlier runoff: "I think I am not a fisheries biologist so I do not know exactly what cutthroat trout need, but I would think that this could affect the habitat that they need for their optimum life cycle. I am thinking it could be a negative impact, but I do not know how it would affect the whitebark pine or the beaver."
- More frost-free days: "Well again, in order for the water to stay in place as long as it has been and to slowly melt so we get the benefits a little bit longer runoff time and for glaciers to not be disappearing. I would think that if this keeps progressing it is going to be harmful to the species that are most affected by water."
- Rapidly melting glaciers: "Well this is an alarming thing that is occurring, especially if it continues to occur. Again, I think it is going to affect the water flow and that will affect any of the species are dependant on that and I know that everything is in a way, but cutthroat and beaver living in rivers and ponds. So I am thinking that, I don't know unless we can take steps to slow down or try to reverse global warming I do not how else to keep the glaciers from melting."
- Increasing minimum temperatures: "Again, I had Nordic skiing and other snowsports and I did not make them my most important, but I have heard about how some of the ski areas are trying to figure out what they can do next to just be summer fall and spring, to provide things other than snowsport. But as it relates to this, the snowpack is not going to stay the glaciers are going to melt and it will have an affect on species. I know the whitebark, and the cutthroat.

Education, Science and Management (Unprompted mention of climate change)

- "The first thing that comes to mind is funding, with the economy the way it is and the budget at the national level and all the way down the way it is I guess that I am worried that there will not be funds devoted to research and I think there should be. I do realize that if the economy completely tanks then you have to have food and clean water, and there are certain basics that you need to have. I understand that research could have to go for a while, but I hope they do not go for ever. I hate to bring politics into this, but I am a democrat living in a republican state and I am tired of people not even thinking that climate change is happening. So I am worried that if republicans stay in Washington then there will be less emphasis on money for research."
- Earlier runoff: "If they do this studying of these processes then they will be looking at what affect it might have on them."
- More frost-free days: "Well this happening is going to affect aquatic habitats and water process, and studying it will give us information to see what the affect is."
- Rapidly melting glaciers and 4: Same thing about studying it.

Participant #18
Personal Irrigation

- "I think the management of the water resources from the state engineers office and the bureau of reclamation that determine a lot of the surface water flows and where they go, and who gets what, and how it is delivered and appropriated. I think that is a big deal to a lot of people, especially some of the smaller people around town that have a five acre piece that need to water their pasture to feed their horses, feed their cows, irrigate their gardens, ponds and lawns. I think it flows to the top whenever you are talking about peoples lives."

- Earlier runoff; "I don't. I think it will affect the operations of how they operate Buffalo Bill and Yellowtail, and Boysen, and it is going to change that, but I think that can be managed to cover for that."
- More frost-free days: "Possibly, I think it could."
- Rapidly melting glaciers: "No, it affects a lot of these other ones that we talked about in the pyramid. As far as the most important ones, pretty minimal I think."
- Increasing minimum temperatures: "I think so. There is going to be more evaporation, less water in the system. More demand. A lot of it is tied to economic growth as well. It depends, but I think it is going to reduce our overall water coming out of the forest. A natural warming trend, it all depends if these trends are consistent I think that is what is going to happen."

Municipal/Household Water

- "I think there is a lot of money invested in the municipal water systems, especially in the Cody and Worland area, and I know there is a lot of investments in pipelines and delivery. They have expanded their pipeline recently and they are trying to extend it out to other people in the basin, but I know that people hold on to their water rights really tight. Especially in this country."
- Questions 1: "I think the household water is probably the same, depends on the municipal source for the water. A lot of the communities use wells, I don't think that would be an issue as much. Some of the communities that have surface water diversions, that could affect them slightly."
- "Yeah, and I think one of the things that is going to due it is going to force more water consumptive use. So they will need it, consumptive use will go up because your lawns, you will have to be watering your lawns more, watering your crops a little bit more."
- Rapidly melting glaciers: "Same as above."

Participant #19
Commercial Irrigation/Household Municipal water

- "Ok, now, my personal thing here in Worland we are off an artisan well coming off of the Bighorns. I am thinking here, the Shoshone and the people that live on that side, there has been no end of studies from the 20th century, way back to the early part of it. That showed the most important product coming off the western national forest is water, it is not timber, it is not livestock, it is not mining, it is water and because the drains in the west off of the high country down to the dry country. And, so, that is the most valuable monetarily product coming off the forest. Now in Wyoming, that irrigation ranks right up, the commercial irrigation water rights ranks right up there at the top of everything, second after that is municipal water supplies, and then personal/household water supplies for those people that are not, anybody that I know of, here in the basin is pulling water straight out of the river groundwater for household, they are all going into wells. But some of them are very shallow wells out through there, and frankly, we are in a desert here where we are getting 6 inches of rainfall a year. And you have gotta have water to have a house, and it has to brought in by pipeline or you have your own pipeline supply out of a well. So that is why I ranked those two right up there at the top, it makes agriculture possible, there is not. I grew up in Texas, and a lot of it was dryland farming in my family, and everything, the rule has always been anything east of the 100th meridian you can make a living farming without irrigation, west of the 100th meridian you need irrigation unless you are very lucky. And, again based on my family, crops west of the 100th meridian that are not irrigated you average a paying crop one every two years. And, so, commercial irrigation we are talking, there is not a dryland farm in this basin. The closest that I know, is down almost to Casper. There is a dryland farm down there that raises wheat. I am not sure if there is any on the other side of the bighorns, on the slope there, I think their might be some dryland farming, but most of that is irrigated too. That is the whole story right there, we did not in our early history, we did not have a lot of industry coming in depending on our water supplies. That was sort of an eastern thing, where the industry sat by the river and just sucked the water up. Here, we never had that heavy industry. We don't have smelters, we don't have refineries, we don't have anything that takes a lot of water. This Pepsi plant, they started off using water out of the river, and of course as soon as our pipeline to Worland came from that artisan well, they switched onto that. Now, actually, the Pepsi plant makes more money selling Aquavista than they do selling Pepsi-cola, but they are huge. They supply most of Montana with Pepsi products, Idaho, and Utah. So, I don't know that is the way it is."

- "Maintain these two, the Shoshone needs to continue to provide water recharge to this ecosystem, and runoff to keep these two going. Now a good part of the Shoshone, and I think it is getting, we had the Yellowstone fires up here (Clarks fork) that slopped in up over here. Burned off a tremendous amount of timber, and for years, and years, and years after that the Clarks Fork ran really muddy and carried a lot of sediment, and it came off fast. To me it seemed like an awful long time to get enough vegetation going back on those burned areas to where they could start holding that water back. Frankly, a lot of the value of that country as far as water production was lost during those fires. It wasn't the timber values, it was the water producing value, the fisheries suffered through there a tremendous amount, and I was a fisheries biologist up here and I would go up and look through there, and in the spring there would be large numbers of dead trout floating down through that whole thing, because they could not survive the winter. As soon as everything was thawing out the dead were floating downstream, and winter kill is common everywhere you have ice and snow, but it seemed to be especially heavy here after those fires. They might have survived the first, but the habitat was changed around enough and water flow pattern changed enough essentially your winter flows greatly decreased and the fish have a very difficult time surviving low flows in the winter."
- Earlier runoff: "Yes, commercial irrigation, there is no doubt about that." "And, household water, yes it would, probably because the earlier runoff is sort of catching the ecosystem by surprise, and I do not believe that this early runoff is getting as much infiltration into the soil and through the groundwater to recharge the groundwater table. Mainly it is because what I have seen here is that the runoff is occurring because you are having warmer days early, but the days are still short and the plant growth is largely determined by daylight length more so than daytime high temperature, and so you have this sort of stuff where you are having warm days and frost every night. And, you are not getting, the vegetation is not intercepting because the snow and the winter everything is laying down and it is dead. Along side the streams on the upperbanks the standing grasses and the furs are sticking up and it intercepts the water and it spreads it out higher on the floodplain where it soaks in to the warm soil. But, what we are seeing here is often a case of the timing, when it is up here in the middle of

the day it thaws out, and by the time it gets down here it is midnight, and the ground and everything is frozen, and so you do not have that water infiltration into the banks down here in the lower reaches. A lot of the times the high water down here is not during the high part of the day, it is during however long it takes to get from the upper reaches where it is melting rapidly down to here is often times a twelve or 16 hour, or 10 hour lag and by then the soil along the river banks are frozen. The lower stream banks are frozen again, and they get a little water up there on the tops of them, but you do not get a lot of infiltration, and the other thing is that I am convinced a lot of the infiltration of the groundwater is due to earth worm activity. The BLM has a lot of history of trying to show that if you exclude livestock from the stream, you go from bare banks and from dry bare soil to grass and shrubs and a litter of covered things. All of the sudden you can change the stream from ephemeral to an intermittent flow, to possible a perennially flow. Most of that is just changing the infiltration into the banks, it is not that you are stopping that much more infiltration because you have the organic layer that makes earth worms, and you have all these holes going down through and past the roots, and so earth worms have changed lots of things. When earth worms, European/English earthworms were introduced to New Zealand, the pastures got more fertile because the earthworms had so many holes and their droppings in the little mounds fertilized the soil and kept turning it over. I think the worms are the unsung heroes."

Participant #20
Preserving lifestyles, livelihoods,

- "Positively would be good management of the resource, trying to preserve what is already here without losing it in the future. Having been born and raised in this country, and spent much of my life in both the upper and reaches of the watershed, both around Dubois and Cody, and then down here. In 61 years I have seen a lot of changes, most of those changes are the influx of population. In 61 years I have seen a lot of different winters I guess you might say, different snowpacks, different rainfalls, to me it is pretty cyclimatic that I have seen over my lifetime. I see one of our biggest challenges is to manage the resource and also manage the people that are using. I think that is one fo the big challenges.
- Earlier runoff: "It could, you are going to traditionally you are going to your fishing season, tourist season, spawning season, all of that have acclimated to when the runoff a lot of times happens. Again, there is climate change, there is no getting around that, but whether that is going to stay in its present direction is anyones guess, I guess that is one of the big debates, is it or isn't it. Again, cyclimatically over my lifetime, and talking to a bunch of the old timers in this country. We have had two or three where there have been twenty to thirty year climate switch, and things keep changing back and forth. And whether we are in the middle of one of them, I don't know. Will it affect it, of course it will affect it. But whether it will continue to be a big issue, we may be wishing for warm weather one of these days."
- More frost-free days: "Most definitely, personally I kind of enjoy more frost free days. I get to grow more garden, more fruit trees. It is actually benefiting me personally, because I can grow more stuff."
- Rapidly melting glaciers: "They very well could. Number 1, if a lot of the glaciers, and I am going to say again in the upper reaches of the drainages provide not only the recreational and the personal landscape and lifestyle there is more water during the summer."

- Increasing minimum temperatures: “As far as the snowpack and snowmelt, yea it could, but again if we get a raise in temperature we are going to get more moisture coming in. Is the raise in temperture going to affect el nina, la nina effect, which causes whichever one it is. We get more rain a lot of the time in the summer with a raise in temperature because of the evaporation of the water sources, etc., etc. Will it affect it? You bet, is it going to be detrimental or is it going to be good for us? I guess in twenty years ask me the same question.”

Personal Irrigation

- “Management of the resource again, as your population grows, as you get more people you get more water use. Trying to maintain the water use for irrigation is going to impacted not only by the number of individuals pulling water for small yards, drinking water, takes away a lot of the times from the agricultural water source. Luckily, in Wyoming we do have the senior water rights that go with the land, but I can see challenges coming up if the population of this area grows much more, and or the downstream users all the way to the Gulf of Mississippi, because that is where our water ends up. If they start challenging because of population growth and use, the amount of water that they will need could impact what we do in the headwaters of the watershed.
- Earlier runoff: “Pretty much the same thing, luckily on the bighorn river, being downstream from Boysen Reservoir, most of the time they are going to catch the earlier runoff. Where it is going impact people is on the upper reaches of all the drainages where they don’t have the dam storage above, and they are trying to pull water when they can. If we get an earlier runoff, and it quits when they are trying to irrigate then yeah it will definitely impact it.”
- More frost-free days: “Irrigation wise, yeah it will affect it again, your ground is going to dry out quicker. Depending again on our rains, I mean, along with some of the frost freer days, I have also seen more rains, earlier rains. Which in the lower reaches of the drainage benefits, in the upper reaches the rain causes a greater and quicker runoff.”
- Rapidly melting glaciers: “But also, those upper irrigators get their water from there. If we lose those, yeah it could severely impact us.”

Participant #21
In-stream flow

- “Well, the dams can restrict that and if the dams are not managed properly it will affect everything along the river. The aquatic habitats, the fish, the sediment, the plant life, everything, so you know it has to be controlled and regulated very carefully.”

Natural Flood Control

- Again, the same thing. How the dams are controlled, there have been times when the dams are not managed properly and it has hurt everybody downstream. For instance, last year if they hadn’t managed Boysen the way they did there could have been way more flooding then there was. They managed it beautifully. It was just a perfect management of the whole system.”
- “Well I will tell you, I am sure that you believe in global warming. But me, not so much. I realize that there is an impact from pollution and those kinds of things, but I think our universe changes anyway, and there is nothing that we can do about. It is just oing to happen, and if you look back over water history in the last 150 years when it has been

recorded. You will see that a lot of the same scenarios have played themselves out over and over."

- My prompt: "So, you do not see these changes as a threat to either of those two things?" Her response: "No, I don't. Because if we have another drought it will get over with. I think people go overboard on their tree hugging, I am a tree hugger to a degree, but I just don't buy all of this over the top stuff."

Participant #22
Commercial Irrigation

- "Management of land is a very important part of it, if the land is not managed right it doesn't matter if you have water or not. The proprietary management of it; if the irrigation ditches are not managed, if somebody misjudges the amount of water in the reservoir. That could affect the commercial irrigation, could affect the crop, which affects the farmers, which affects the local businesses and everything else."
- Earlier runoff: "It will without very close management. We hear a lot of the hotter temperatures coming in, we are getting into a hot phase. Through history I think that we have seen this, you go from hot climates to cold climates, they just kind of rotate themselves. Back in the ice ages it was drastically different, you know it is swinging the other way now. I do not know that we are not just in an every how many thousand years it takes to make this change, then it could go back the other way. During these times, if these resources are not managed properly during the very very hot dry times, then you run out of the water. During the very very cold times then the lakes, or rivers, or whatever stays froze up then you have no water. It's a very drastic swing that whether it is happening through history, or its thousand year swing it still has to managed properly. A 4 degree change from the 50's to the 90's is quite a change, and it has got to be taken into consideration before we reach the point that it changes the other way, then you have to start swinging back. It is just an ongoing observation, and management practice I think."
- More frost-free days: "Biggest affect that I see is that you get the snowpack around here is what gives us the water during the summer, and during the year. So if you start having later cold days, and gets start getting cold later and later, and warm earlier and earlier you have more rain instead of snow, and the rain runs off right now. If you have rain late in the season on the snowpack, then you bring snow off with it. It speeds the process of the timeframe that you have to manage it."
- Rapidly melting glaciers: "Again, that is your reserve up on the glacial points. As that decreases then you have less and less reserve. If the temperatures keep getting warmer and warmer as we get through the years, then your reserve up on top is a lot less and if gets completely depleted then you have no reserve so one year can ruin you."
- Increasing minimum temperatures: "Right it just again, it just shortens the period that you have to manage it and also it depletes the reserve up on top at the glacial points."

Household/Municipal Water

- "If it is not managed right then the quality of water that is coming down the stream is not potable to drink, and if it is not managed properly then you don't get good potable water for drinking water. These regions have some of the best water in the world, and it is very important that we manage and take care of them for the future. If not, then this area would virtually die without water."

Participant #23

Preserving lifestyles livelihoods, and landscapes

- "Basically for this it is just the flow of water, in other words. If we, we are not in the big drought any longer, but when we were in the drought it was a significant problem. We have a reservoir up here that is basically built for storage for irrigation, and we have a pretty vibrant ag community and over in Big Horn county, and actually Washakie county also. None of it is dryland farming, it is all irrigation. I am kind of a proponent of good, sustainable, economies and economic development. Not everybody can build a part, I am pretty supportive of the ag community. I had some exposure to it when I was growing up, hard working folks and all that. So the importance of continued water flow and all that is huge, and we have actually had a nice couples years in that regard."
- Earlier runoff: "No"
- More frost-free days: Same
- Rapidly melting glaciers: "It could, but I think we are in a quote warming cycle, and we may as humans exacerbated the problem with our burning of hydrocarbons. Actually, the drought seems to have ended in this area of our state, and we have snowpack on the Southfork from last year that never melted. It is almost like maybe that is not an issue. As far as sustaining the communities around here, they have the first call on all the water, and the reservoir may be taking down to this deep. So it may affect the recreation, but I think we are in pretty good shape in my lifetime anyway."
- Increasing minimum temperatures: "yes, but only in that I think it would affect, it could conceivably affect the amount of storage that we have on our reservoirs. The release in relationship to when it is called upon by the industries around here, which are primarily ag and obviously the municipalities. Aside from that we are in pretty good shape here. Probably, we are supposed to have a wet winter, although we haven't this year yet. We are supposed to have a lot of moisture this year and next year. But the summers will be like the reservoirs will be full, but if you get a hundred yards away you might spontaneously combust. I have friends in the FS here and I always maintain every, mid October, when everyone is done elk hunting, light one of those drainages on fire because when they catch on fire one of these summers it is going to suck. It is going to be worst than the 88 fires, from the beetle kill. There is a huge amount of fuel there."

Commercial Irrigation

- "Same thing, I think especially when you get east of Cody. I mean, Cody is like a little bedroom community like a suburb of Denver or something. Where you get over towards Powell and Lovell, they are ag communities and they depend on it. Everything that has to do with those communities, they need the sustainable supply of water, and that is why we have this big reservoir here and that is why those communities are even there. Most of my water thing is recreating, I just, my boys are more into hunting nowadays, and most anything you do hunting around here there has got to be some water. Whether you are hunting pheasants and sage chickens and that sort of thing, and they are in the fields. Thye are not in the fields here, they are in the fields over there. And the fishing and that sort of stuff."
- Earlier runoff: "No"
- More frost-free days: "I mean I don't think so, because basically everything that we do around here that has to do with water, basically is the storage either in the reservoir or up in

the mountains. When it comes down it is going to come down for three or four months. It doesn't really matter what three or four months it is, I mean obviously if it were in January or February that would be a big issue. But whether it is in May through August, or June/July through October. I think it would be a pain in the ass for the farmers, but I think they could deal with it. I mean the water is stored in the reservoirs. Last year that dam near emptied that sucker out by May, and then it filled up in a hurry."

- Rapidly melting glaciers: same

Participant #24
Water Quality

- "I do not see any negative right now, I just think that it is very important. I do not see anything in this area. I do in populated areas."
- Earlier runoff: "I think an earlier runoff would."
- More frost-free days: "Well, yah, I mean I do not believe it is drastic, but if is a big word."
- Rapidly melting glaciers: "Yeah, it would."
- Increasing minimum temperatures: "Yeah, but I don't think it will be a big problem."

Household/Municipal water

- "Not at this time, not in the Cody area."
- Earlier runoff: "The ability to get it, yea, I am sure it would."
- More frost-free days: "Yeah."
- Rapidly melting glaciers: "yeah"
- Increasing minimum temperatures: "yeah, but I feel like the survey is slanted."

Participant #25
Household/Municipal water

- "The Forest Service trying to steal everybody's water rights. Well the best thing is that we are on the front end of the water, we get it first. We are on the upstream side, location is number one is positive. We get the first part of it. The older water rights, most of us have older water rights and downstream. That is a good thing."
- Earlier runoff: "No because we have the reservoir, but it is negative, if it affects them at all it affects them negatively because the water has already gone down to Mississippi because it doesn't come off slow enough, so that is a negative deal. I know all about that starting early, we used to have peak water here around the 4th of July or the end of June, and now it happens even towards the end of May."
- More frost-free days: "They are having frost too early sometimes now, and frost too late because it is killing the beets. Well they froze the beets here two years ago, and that is the earliest it has ever frozen. And so they have had late freezes have killed the beets in the spring, so whatever that means. I do not think so."
- Rapidly melting glaciers: "Is correct, because all of that water is gone and so it doesn't come off later so you cant irrigate. I am not in the Wind Rivers, but I am familiar with the studies. My Dad used to farm down here, and he had to irrigate really early in the spring because the water was all gone later. You have got to get the first few, you got to put the water down first because you don't have it later. It is all dried up. The longer the water coming off, the better it would be for irrigation. That is the same trouble they are having down in the wind rivers, if the glaciers melt of earlier, the more melt comes earlier and they

don’t get to use it later on. It is progressing, they are melting off. They are not there. This could be a ten thousand year thing.”

- “The biggest thing in these is, we are not on a hundred year cycle, we are on a hundred thousand year cycle. So what we do now is immaterial, because we have had these cycles before. We do not know, short term, yea, but we had a drought here in the 30s.”

Commercial Irrigation

- We are becoming, when it used to be rural agriculture, now we are becoming rural residential, and all the land has been subdivided and that is a negative factor. We are losing agriculture and putting houses on it. We are losing our agricultural base, and people don’t want cows on public lands and we are losing that. All of the private land is going to be subdivided for houses, and you wont be able to use the BLM land and the FS land for agriculture because you don’t have no base.”
- Earlier runoff: “

Participant #26
River Recreation

- “Negatively, Kayaking, canoeing, a lot of those raft companies and things the people bring debris down the river which creates pollution. Such as flip-flops, life vests that are not recovered, things like that. Which birds and other animals get tangled up in. As far as positive, it does give recreation usage to all of those. National forests in our areas are profiting from the use of that.
- Earlier runoff: “Not generally, I think if it starts a little earlier and it also depends on our snowpack when that actually starts to runoff. Last year and the year before were late in the year runoff, so that, which means technically winter is not starting as earlier as it normally would from Thanksgiving on, and we are receiving more precipitation in may which we generally have not.”
- More frost-free days: “Absolutely.”
- Rapidly melting glaciers: “yeah, I mean we are certainly going to see certain flows in certain rivers that depend on that glacier melt to sustain, they would actually disappear, it could possible disappear.”
- Increasing minimum temperatures: “I don’t think it is going to affect it, it just starts it earlier.”

Supporting of commercial land-based recreation (Unprompted mention of climate change)

- As far as supporting of commercial land-based recreation areas, I think golf courses are the biggest waste of water. There are other grasses out there that can certainly survive with a whole lot less water, and it also has to do with the time of day that you water a golf course, which can benefit the grasses and the greens can benefit. As far as snow making, it is absolutely important for ski areas to have snowmaking because they cannot make it on their own with the global warming that is happening right now.”
- Earlier runoff: “I do not truly think that global warming is affecting this, except that irrigation for golf courses is being, they are grasping it sooner.”
- More frost-free days: “And certainly the use of the water for golf courses and snowmaking, for sure, because that is nine more days that it is actually absorbing into the ground.”

- Rapidly melting glaciers: "That one is kind of a grey area, the golf courses certainly do. Sleeping giant is kind of unique because it has a river to draw its source."
- Increasing minimum temperatures: "Also, just like golf courses it actually gives golf courses the opportunity to use water earlier, which is not a good thing but it is what it is."

Participant #27
River Recreation

- "The really cool thing about the Northfork is it is almost all wilderness, so there is not a chance for them to mess it up too bad, because you are above the reservoir. Almost all of the water that comes into this drainage comes out of the wilderness, so the FS cannot affect it positively or negatively, which I think is very good."
- Earlier runoff: "No."
- More frost-free days: "You know when I was growing up, we used to always get a week or two of below zero whether, we do not usually get that now. I remember 20 or 30 years ago we actually went through a winter it never got below zero, but I mean you grow up and you think weather is stable and it always got below zero."
- Rapidly melting glaciers: "You know it is one of those things that I do not think man controls it. If I could control it I would say lets not have those glaciers running out. We do not have too much control. Not affecting on the Northfork, and you talk about the SNF, you would probably get a different demographic down on the Wind River because the Wind River is where the glaciers are melting. Here we have the Fishhawk, we have permanent snowfields.
- Increasing minimum temperatures: "Probably would."

Glacier-based services

- "I really like the idea that we have got the glacier based water, we don't get it so much here, it is more down on the Wind River. Yeah, it is fossil water and it is cool that it can come out in years that are drought. Like on the Northfork, we have got a few, certainly some permanent snowfields. The Fishhawk glacier actually had a crevasse in it 20 years when I was in there, and I am not sure that it does anymore. Like Dean said, possibly they are rebuilding. I mean the glacier thing is such a complicated thing about climate, what is going on with that, and of course once that flywheel gets to turning, which it has been in the negative recently cause they are burning out, it takes a long time to reverse that I would think and surely we have not."
- Earlier runoff: "That is not something that we can affect is it? That is just kind of one of the bad things that happen with the fact that our glaciers are melting."
- Increasing minimum temperatures: "Yeah it melts them out."

Participant #28
Supporting commercial land-based recreation

- "Well right now I do not see any, because we have had the drought for the past twelve years or whatever it was there, and now we are kind of coming out of that right now. I see, I do professional guiding, and I see glacier building happening in the high country every year right now. From 2004 to now, we are keeping snow and ice in the high country all year, it is getting bigger every year and I notice that happening. I spend up 45 days every year in the backcountry guiding hunters. I am up there in high country, I pass over deer creek pass.

Right now we are getting pretty big glaciers coming back, it was totally gone in the late 90s and early 2000s there for a few years, and since then it has been building back slowly and we have a pretty hunk of ice up there right now that is staying year round. I would say right now it is looking pretty good. I would say that our water levels are getting back to where they were. Way high last summer, the lake never cleared up. It usually cleared up by mid-July, it never cleared up. So water was running hard the whole year.

- Earlier runoff: "Probably not, I do not think the runoff really affects the flow in October, and what happens in the spring is really not affecting. I have seen it when there is no snow left up there in the high country, and they could still run, this river runs pretty good. I would say no that would not affect it."
- More frost-free days: "Probably not in my lifetime, it could if we were losing our water, or water vapor, warming up it would affect someone someday but not in my lifetime."
- Increasing minimum temperatures: "Probably not that I am doing."

Land-based hunting

- "well, not with the water. I could go off on the other programs, but as far as the water you know I haven't really noticed any big difference that would be caused by water."
- Earlier runoff: "Probably not either."
- More frost-free days: "Probably not."
- Rapidly melting glaciers: "It could affect my hunting probably, just by where the animals would be. Not having those glaciers runoff making that grass green up there makes it easy to hunt, because they have green grass to eat and that is where they would like to be. So that would definitely affect that. And, like I said, from 2005 probably we have been building glaciers."
- "Probably not affect my two number one priorities, which are my jobs."

Participant #29

Water quality

- "Our biggest things here that affect water quality are fires, and surface pollution."
- Earlier runoff: "No, I don't. We are actually slowing the high water runoff because of the snowmaking. This water that would normally would runoff this hill would be gone, and we still have water here in snowform till the 4th of July."
- More frost-free days: "No, not water quality"
- Rapidly melting glaciers: "Not to my knowledge."
- Increasing minimum temperatures: "No, I don't"

Non-motorized ice and snow-based recreation

- "Water quality, if we don't have clean water then we cant make clean snow. We need clean water to make clean snow, and we needs lots of it."
- Earlier runoff: "No, ours is more of a lowflow. We start running our water at a low flow in October and November during your lowest time of the year. We actually look at, we are not consuming the water, we are storing it. Our agriculture ditch says sure you can use as much water as you want, because it slows the runoff."
- More frost-free days: "Yes, more frost free days means a shorter snowmaking season. That is what we run on, when we start getting 25 degrees is when we start making snow. If you

kick that back 4 or 5 days, 9 days on both ends of the year then you run four less days. That could affect you over a long period of time."

- Rapidly melting glaciers: "Not unless the glaciers are cooling the air, and so you don't have the warm Chinook winds would be the only way that I could see that."
- Increasing minimum temperatures: "It affects this for sure, for snowmaking."

Participant #30
Preserving livelihoods, lifestyles and landscapes"

- "You mean if they cutoff the water flow, yeah management always affects how they are going to manage this water and how they are going to allow us to use as the public. It could either affect us in a good way or a bad way, depending on who you have in there. With the agricultural part of it, the farms have got to have this and they got to, so the canal system as far as I understand it comes out of the reservoir and it goes to Powell because that is where the main agriculture is, but they could shut that off. You have the water rights thing and the grandfather clauses and all that, and the cost of it. What they are charging is going to affect them, if they cannot afford to buy the water then they cannot afford to have the ranches and farms. It is all pretty much about management. As far as lifestyles, when you talk to many people around her it is just a matter of time before they shut us off from all of it. Now in the last two years maybe, going up to the reservoir fishing you got to go through the checkpoint, not that it is a bad thing but it is just one more micro management taking away a little bit of our lifestyle that we love, why we live here. Again, it could, I know they do it for a reason, do I agree with all the reasons that they do it…No."
- Earlier runoff: "Yeah, absolutely."
- Increasing minimum temperatures: "More for the livelihoods."

Commercial Irrigation

- "Again, if they are going to develop the farm land out there because it is too expensive, too cost prohibitive to farm it anymore. They can make much more money by subdividing it, then the cost of water keeps going up it is just going to make that transition easier for people that own the land. Again, the commercial irrigation, I know that we pay for that in our taxes and I get that, and I think we should to a point, but again once the government gets in there and raises the prices it is going to be prohibitive for people to continue that kind of life."
- Earlier runoff: "Absolutely, you are going to have a shorter growing season because you are going to run out of water earlier than you should."
- More frost-free days: "I think that could positively affect us in a more positive way, it has been a couple years ago, but the beet farmers around here because of the, they lost most of their crops because of an early frost."
- Rapidly melting glaciers: "Absolutely."
- Increasing minimum temperatures: "Probably not too much, it would for the recreation part of it, but for irrigation I do not think so."

Participant #31
Commercial Irrigation

- "Increased pressure from conservation groups, fishing, in-stream flow and anything like that would influence the ability to use it for commercial irrigation. But remembering that the whole system was set up for commercial irrigation in the first place."

- Earlier runoff: “Not, because we have dams in place. As long as we can store the water.”
- More frost-free days: “It would enhance our ability in agriculture, just because frost free days is more growing days.”
- Rapidly melting glaciers: “Possibly, I mean you would assume that if they were melting more rapidly then it might affect snowpack in the future.”
- Increasing minimum temperatures: “No I do not think so, I mean I am trying to think if it would impact snowpack, or runoff, then I am sure it would to some degree. Whether it would impact our ability to irrigate I do not know.

Preserving of livelihoods, lifestyles and landscapes

- “They go hand and hand.”

Participant #32

Lake, Reservoir, and River-based Hunting

- “Well I think we always got to have hunting and all that, it is a recreational, it is the only thing that I do is what I based that one. It is hunting, I do not ski anymore, and I do not do any of that. Now we are talking about wolves, we hunt up here on the Crandall Area and all of those wolves have migrated in a different way and that makes me a little mad.”
- Earlier runoff: “Not really.”
- More frost-free days: “Same there, yeah.”
- Rapidly melting glaciers: “Same there.”
- Increasing minimum temperatures: “No.”

Commercial Irrigation

- “All of these subdivisions and stuff around here. We have always told them that the ground water is right there that wont affect us for the sprinkler system and stuff. So they have been fighting all of that, so I think the farmer should get the water first.”
- Earlier runoff: “It just depends on how much snow we have up there really to me. Because I mean we might have snow earlier and it gets warm and runs off too fast, and it don’t do anybody any good.”
- More frost-free days: “Yeah.”
- Rapidly melting glaciers: “No I do not think so.”
- Increasing minimum temperatures: “You talking about it if is warmer, hotter. Yeah.”

Participant #33

Personal Irrigation

- “Shortage of water in the dam, that would be the. You have to have that water. Is that good enough?”
- Earlier runoff: “No.”
- More frost-free days: “No.”
- Rapidly melting glaciers: “Maybe over a long, long period of time. Nothing that we have to worry about, but maybe over a long period.”
- Increasing minimum temperatures: “Maybe over time too on that one.”

Preserving lifestyles, livelihoods, and landscapes

- “No.”
- Earlier runoff: “No.”

- More frost-free days: "A little bit."
- Rapidly melting glaciers: "No."
- Increasing minimum temperatures: "Over time."

Participant #34
Household/Municipal Water

- "Well I am speaking as county planner and also as a resident of the county. I work a lot in water issues where we have a, if we have good water as taken as a given like here. If we have bad water; we know it and it is an issue. I have a water project, I am not doing it, it is happening in my county. There is a water project, very ambitious, bringing water down to Kirby right now, and it may even come south of that to the Lucerne area. There are water districts that scramble a lot ot provide municipal drinking water, domestic water and it's a big issue, it's a big deal. I live in Worland, and water is a huge thing there. There biggest industry in that town is Pepsi, they are bottling beer, and they are doing soda pop for the whole western region. Somebody told me they have half a billion dollars worth of Pepsi products that are manufactured in that facility. So there is a whole community that is built around the making of soda pop, look at all the grain grown here for beer, we have a whiskey plant in Kirby. These are industries that need water, and the water coming out of the Bighorns into the aquifer that serves the Manderson area. That Manderson water serves the municipal area in Worland, it is serving down to Kirby and coming closer to here. That water district was looking into drilling some wells in this county, and based on water quality and fear of impacting aquifer that ceases. We can get a little crazy and say that here in Hot Springs County, the fact that we have hot springs, incredible hot water resource that is not even tapped into. Right now we are concerned about people tapping inappropriately or incorrectly into that resource and actually compromising it. So we are looking at the possibility of regulations that would guide people and prohibit inappropriate technology, but guide people into using correct technology to get household heat from thermal water. That goes away from the domestic thing. Through this office I see a lot of people that are concerned with their domestic water, I work in the county and not in the city. The cities have municipal water and treated water in the county, getting water can be hit and miss in the west. A lot of people might move here from one coast or the other and figure getting water is not a problem, you poke a whole in the ground. Well, it can be a problem, you can get bad water, you can get no water, you can get inadequate flow. These really drive issues, there are developments that I have seen worked, more in Montana than Wyoming, there are subdivisions on the Platte that say no potable water available. These people haul water, they expect it, that affects the value of the water, and you see people driving 50 thousand dollar pickups with water in the back. Recently working with 2 land owners west of Kirby, that want to get plugged into the Kirby water because they are hauling water. It is a big issue, having reliable top quality source of domestic water is a big deal for us. We want to turn on the tap and get good water, and not everybody can. It is something that is always on the surface. In the scheme of things, and looking at this pyramid here, and looking at all these good values, altruistic things, and spiritual values and recreation and all that. They are all important, there was not a single thing on your cards that was not important, and yet what is at the top of the heap…the need for domestic water."
- Earlier runoff: "I really don't know. I think it could, I mean the big thing for us, or so I have been led to believe it keeping our snowpack. I assume and early runoff is a more

rapidly melting snowpack, which is generally perceived, my kneejerk reaction is that is not a good thing. So I think it could in the long run. I am not trained in any way, or educated in aquifers, and how they recharge. It could be that any earlier runoff would not affect aquifer recharge, and therefore affect municipal supplies."

- More frost-free days: "I do not see that as an impact."
- Rapidly melting glaciers: "I am not aware how much water volume is held in glaciers, and I think of glaciers as not snowpack and not ice field. Our concept of what is a glacier and what is not may change, it may be different. I do not think it would substantially impact municipal water because if it is held in glaciers it is not getting into municipal water. I do not particularly need glacier water to sustain municipal use. I do not think it is impacting that. I think keeping our snowpack longer is generally a good thing."
- Increasing minimum temperatures: "I do not think it would affect."

Preserving lifestyles and landscapes

- "This was a trick question here, because I like livelihoods, lifestyles and landscapes. So you used buzz words that hooked me. A healthy agricultural communities is big to me, large working farms and ranches is big to me, I used to work for the stock growers association. One of the times I quit planning in disgust, there were several. Without healthy agricultural everything falls down, failed ranches turn into mediocre subdivisions, and then you start really having water problems. It is crucial to the landscape, and then that becomes a spiritual factor in a sense, these two, you could make an argument, this is really stretching. I could make an argument that these two topics here more so than the others, connect to the others and lead to the others. LLL involve recreation, involve spiritual. I drive 30 miles to work every day, I hate commuting, but that is an awesome commute, it is a spiritual experience to commute. That sounds weird, but it is, at least mine is. I guess if I lived in LA it wouldn't be a spiritual experience, it would be dark. This is, you could say that is the kingpin right here. If you were to say pick Participant #1 that would be it, because it is so broad, because it is so all inclusive, and because it touches on the other, on so many other categories. I drive to work, I see dry landscapes, which are the absence of water, and yet they are enhanced by water. I see a great deal of agriculture, I see evidence of mineral extractions, which relies on water and produces water. It gets more and more complicated, I see communities here, a whiskey plant in Kirby, which cant happen without water. I see livelihoods that are tenuous because they are based on water. Agriculture is our mainstay, and yet it is not our biggest employer. It just occupies most of our private land, and much of our public land and in that sense it is a big thing to us, it is something that we identify with. Actually the top ten biggest employers in this county are energy companies, and yet water companies is crucial to those as well."
- More frost-free days: "I could see that as potentially a negative impact."
- More frost-free days: "Could affect lifestyles and landscapes, I do not want to be too capricious here, but actually here is the deal. I have spent the last 20 years in Wyoming and Montana, the stronger our winters are the more the riff raff keep away, I am being silly a little bit, but there is a truth to that. As our winters get milder, our population will increase. I am concerned about how it will impact population dynamics here in the basin."
- Rapidly melting glaciers: "It would not be a good thing."
- Increasing minimum temperatures: "I do see it impacting our general well-being, ambiance about living here."

Participant #35
Commercial Irrigation (Unprompted mention of climate change)

- "We are faced with a fact of climate change. The potential and some of the predictions have been wildly quoted and misquoted and everything else. If we were to lose significant amounts of forest cover over large areas we would become, the streams themselves would become, a term called "flashy." Where they flood or they don't run, and nothing in between. That is a huge deal for all aspects that we as a community are dependent on, and those of us who are in agriculture, fortunately we have reservoirs, but even those would be so manifestly affected by streams that flood, bringing huge amounts of sediment and then they would go dry. Your ability to store water is disturbed when you have such huge sediment loads. And so, and then all the other things that are the reason that we live here, like the ability to fish and hunt, all those kinds of things, and enjoy the open spaces, you notice that we are all outside recreators, at least most of us are. We walk our dogs; and three miles is nothing for us. The ability to get out and enjoy the country, all that is really affected by what surrounds us. The force particularly is somewhat remote from us in our everyday operations, but it is integral still because it is the high country it is where we get; we live in an irrigated desert. That is what you have to explain when you go talk to someone in agriculture, like I just got back, my brother lives in Kansas; "we live in an irrigated desert high country valley" and people look at you like, I cant put that together it is too many adjectives. I think it is important to understand that we are dependent on this commercial irrigation, though I do not think of myself as a commercial irrigator. It is a huge enterprise, it is what we are dependent on. We would live in a desert valley if it were not for that, and all of the service industries that serve us like the fuel guy, the fertilizer, all the dealers that supply seed; they would have to be gone because we would not be here. Then you got the parts man, and the guy that fixes the tractor, and the guy that owns the tractor shop, the guys that services my pickup, there are just so many spin-offs of that. In ways too, it is just part of the history. We are in the museum cultural center here in Hot Springs county, you look around and almost all of the; you look at old photos and there is a doctor, but he also had a ranch. Or there is a dentist and he had, or there is a cobbler and they had a place up Owl Creek. They are all dependent on that, so it is all woven together into a web. You know, hey even out on the farm we are dependent. The springs, the ponds, I am developing ponds right now and the wildlife is dependent on that. The birds come in and land, and they did not do that two three years ago before I had the pond. Now they are landing there, you are getting some good growth. If that irrigation wasn't there, all of that would not be here or at least to the extent that it is. Fortunately we have a number of dams that they control the ups and downs, two years ago in the spring this town ought have been in big trouble had there not been Boysen. I was in big trouble because Anchor dam run out of storage, and it flooded across my field. I lost half of my ability to produce. Commercial irrigation in a lot of ways has built flood storage and flood control like I have been paying for 39 years into an irrigation district that has been paying for the building of the dam. So I believe in dams number 1, I think they improve the fisheries above and below. Where is the best fishing in Wyoming, the miracle mile between two dams. Fly fishermen come from all over the world to fish it."
- Rapidly melting glaciers: "It is interesting after these last two springs they have grown. It is going to be interesting to see this over time; the Dinwoody is a huge glacier for us, it supplements the river, it is temperature control, multiple species, all those things that are

positive. And it was declining, there was no doubt about it. It will be very interesting because we have no had two very wet springs, that documentation I do not have it. It will be interesting to see."

- "Natural flood control yes, commercial irrigation because we built storage not in the short term, but in the long term yes. Because we will see more sedimentation enter those, which lessens the ability to store and more sedimentation involves damage to particularly trout species, which is my favorite."
- "I do think it will be interesting to track over time, because I do remember being told in school in the 60s that we are going into an ice age. Global cooling, you have so much smoke that is entering the atmosphere that the sunlight is being reflected back and we are going to use more energy. It was going to be this cumulative affect that was going to lead to the next ice age, and now we are the other way around. Suddenly there is this big question mark over my head, I am a skeptic now. Let's god and nature take it and learn."
- "Some of the things that I put last like Native American cultural and spiritual values, that was way down at the bottom, I mean it is not going to be affected in my opinion by climate change, and the ability to produce in the area and to have a reasonable balanced community. We were dependent on that river, and that river comes off the forest. A huge amount of that because from about 8000 up is where most of the precipitation falls in this country."

Natural Flood Control (Unprompted mention of climate change)

- "The way our system works is dependent on that natural flood control that occurs because you have high timber and above timber line even. High places were the snow gets blown into deep draws and lays there and maybe even becomes glacier, and then naturally those are released slower and over time. The factors to me are not, it is in my opinion, and this is based on observation, 58 years of observation if you will, we as human beings like to think we have a lot of control but when you get in the high country you understand that you are a visitor. You are not natural, and you see those two or three hundred head of elk, and you get up into the sheep country, it is awfully wild. And so, the factors that are going to affect th natural flood control or even the commercial irrigation. I will say that when you think about how a forest should work, ideally having multiple species of trees and multiple ages of trees. Those are the factors that I think will help us, if you look at the Shoshone right now, you see a dead and dieing forest. More and more red trees that are turning grey and falling, and I see a tremendous possibility that 1988 is going to come back. In 1988 one third of YNP burned, if we have that same kind of a summer where 1/3 of the Shoshone burned we would see flashy streams, we would see riparian areas damaged for years. We would see a tremendous growth of Lodgepole pines all of the same age, and the whole system would start building and aging all over. Hopefully we can get a mosaic of burns, and hopefully we can get a mosaic of timber in places where we can manipulate the landscape so it doesn't all burn at the same time. Fire is a big part of natural flood control, and what happens on the forest. Fire is a huge part of that, up the Greybull the "Venus Fire" burned about 4 or 5 years ago, I cannot remember the year, but below there the fishing just collapsed for several years just because of the sediment loads. Huge sediment loads. So natural flood control, and the factors that impact that in my opinion fall back to a portion of us and a portion to the natural ebb and flow of wet times and dry times in Wyoming. If you look at tree rings, it has been that way for a long time. There have been good times and bad times. So that is my opinion about that man ought to where he can, manipulate to toward the idea that, you never reach ideal, but you should try where you can to manipulate to where you have that natural succession of different species where you don't have all doug fir, you don't have all Lodgepole pine, you don't have all of the same age in a forest and you will attain natural flood control and you will enhance commercial irrigation."

Participant #36
Biodiversity Conservation

- "Noxious weed invasions, annual grasses, we have got major problems in the west with noxious weed invasions and that decreases diversity of natural plant communities and ecosystems. That would be one factor, there are a whole number of issues there. That is why it is really important, there was a saying that Leopold once said, "if you quality in environmental habitat for wildlife and fisheries, then you have outstanding excellent habitat for humans." That is why I picked these two, it is really important that we try to maintain ecosystem function and structure."
- Earlier runoff: "I do not think so, I think it may enhance diversity particularly if you get areas you get peak runoff and more wetland habitat that always translates to higher diversity in plant and animal species, usually unless there are other conditions."
- More frost-free days: "You talking about global warming then, the implications. As far as habitat diversity, biodiversity conservation I do not see an impact there."
- Rapidly melting glaciers: "I do not know how to answer that, I guess it would depend. I don't see an impact, I would say no."
- Increasing minimum temperatures: "It may affect biodiversity again I do not know. I don't think you would see major shifts."

Nutrient cycling

- "There could be issues particularly on agricultural land where they use a lot of insecticides and herbicides you get that runoff going into the aquatic systems, and certainly that is going to increase nutrient loads and reduce nutrient cycling."
- Earlier runoff: "Earlier runoff depending on the peak flows, and the amount and where it is coming from, and how much sediment it is carrying, there are all these factors could certainly impact nutrient cycling and sediment transport negatively."
- More frost-free days: "I don't see an impact with nutrient cycling, unless it is a very rapid change over a short period of time."
- Rapidly melting glaciers: "Possibly, depending on where that glacial melt is occurring, and what substrate it is running over in terms of sediment loads."
- Increasing minimum temperatures: "I do not think so."

Participant #37
Conservation of keystone species (Unprompted mention of climate change)

- "The way the weather has been is affecting it, and so, I think it is important that we make sure that we maintain the beaver and cutthroat trout and make sure that we do all that we can to help them. If we have to it in the study area, that is what I want to see done."
- Earlier runoff: "No, because I think they will adapt."
- More frost-free days: "It is going to adapt."
- Rapidly melting glaciers: "No."

- Increasing minimum temperatures: "If it was, I think all these plants and animals in the systems, the water flowing I think it will all adapt as long as it is not fast."

Nutrient cycling
- "The weather and manmade things that are going to affect this one. Like roads that maybe they put in the drain underneath the road incorrectly."
- Earlier runoff: "I think the same, it will adapt."
- More frost-free days: "Unless it is a fast change."
- Rapidly melting glaciers: "I don't think so either, unless it is a really a large glacier and it melts within a day."

Participant #38
Biodiversity Conservation
- "No."
- Earlier runoff: "Oh yea, I think that will change everything. I mean I know that it is changing the habits of the denning grizzly bears, and the plants they eat It is hard to say because it is so complex; I mean holy moly, we don't know what the hell is going on."
- More frost-free days: "Yeah."
- Rapidly melting glaciers: "Yeah."
- Increasing minimum temperatures: "Yeah, it would affect both of them big time."

Gradual Discharge of stored water
- "No, you mean like global warming, No."
- Earlier runoff: "Yeah, but I am not sure that it is global warming. It is global warming but I am not sure who is causing it, because it is all cyclic and then there is a smaller cyclic line running on that one. I am sure that what we are doing to the environment isn't doing any good; there is too many damn people."
- "Yeah, definitely."
- Rapidly melting glaciers: "Yeah."

Participant #39
Gradual discharge of stored water
- "Well a lot of it is going to depend on demand, especially below the reservoir. All the water is appropriated, but the only thing you can do is shift the beneficial uses from agriculture, to industrial, to municipal. The demand is always going to be there, but you have to keep the supply pretty constant to what it is now. There is no way that you can increase it, you can within reason through vegetative management and things like that. Pretty much it is not going to change too much. All of these tie together in a way, because if you take the water out of agriculture and put it into municipal use, you are going to change you stream regimes, especially above the storage reservoirs. That is going to affect your riparian areas, your critical plants, critical species, recreation opportunities, hunting opportunities. You mentioned that the natural storage is enhanced by flood irrigation because you pull it out and it sticks in the banks. There has been a lot of take with the NRCS and Conservation districts have partnership agreements, and they are the ones that do all the farm bill programs. We set the local priorities, and one of the priorities is more efficient irrigation and center pivots are the most efficient, but then you start losing your stored water too. One

time a few years ago, the department of agriculture said ok, this is a good program, people like the sprinkler irrigation, so what we are going to do is write in there: "if you switch to sprinklers then we pay 70% of setting up the sprinklers, all of the water savings will go back into the streams as in-stream flow. Everybody in the state got up in arms about that because it is in violation of state water rights. Then there is an awful lot of different opinions, and negative opinions about in-stream flow having a water right."

- Earlier runoff: "Probably not, as long as there is water in the creek I will use it and store it."
- More frost-free days: "No."
- Rapidly melting glaciers: "I am on a different drainage, there are no glaciers. It wouldn't affect me."
- Increasing minimum temperatures: "No, it would help utilize the water better."

Commercial Irrigation

- "The same thing applies to reallocating the beneficial use. Right now the irrigated agriculture in the Bighorn Basin is by far, it is our life blood. Some counties probably generate more revenue, Park County generates more out of minerals than agriculture, but that is a close second. You take Bighorn and Washakie counties, and a majority of their county income is irrigated agriculture."
- Earlier runoff: "For me personally, or for the Basin. As far as the Basin, most of that is dependent on stored water rather than direct flows so it really wouldn't matter what time of year it comes. For me, on the South Fork, I can't see this trend, of course I have only lived there 40 years. The peak runoff, it can vary 4 to 5 days year to year because of weather, but not because of climate. If in fact it did, four days wont make a difference, but if it jumped a month earlier then I would have, the peak flow would not coincide with the growing season and it would just flow down the creek."
- More frost-free days: "No, I think that would enhance it, and I would have to dispute that because we get frost every month."
- Rapidly melting glaciers: "Not mine."
- Increasing minimum temperatures: "No."

Participant #40
Household/Municipal Water

- "I don't see anything at this point. I chose that because of the health and the well-being of the people living in their homes."
- "household water it would affect it there with less drainage, less water we have to use. But that is saying that the proof would be in the pudding, whether it is happing."
- Earlier runoff: "yes."
- More frost-free days: "I think it can, depending on where you get your water. Whether you are getting it out of the ground, or it is being purified through the dam it does affect it."
- Rapidly melting glaciers: Same as below

Motorized Ice and snow-based recreation

- "Positively, more snow for snowmobiling and negative, gosh we just haven't has as much this year as last year. Snowfall and snowpack. Last year was great, this year was 300 degrees off."

- “I think first we would have to prove that there is a change in climate, but saying there was a change in climate. Of course, on the motorized side it would affect it drastically because of less precipitation and less snow.”
- Earlier runoff: “yes.”
- More frost-free days: “of course it would.”
- Rapidly melting glaciers: “I think it would, once again we got to back to the proof of the pudding. If the data continued then yes.”
- Increasing minimum temperatures: “Yeah it would, because it would shorten the season that we have the water on top of the ground.”
- “There is a lot of room for the hikers the horseback, and actually, in the summer time a lot of those trails can commingle, but we don’t, we lack the resources, we lack the funding in one area, and also I think we lack the drive to do it sometimes, it is easier to pass the buck.”
- “the only thing they are utilizing right now from the snowmobile side is about 20 thousand dollars from the North and the South zones and that is basically right now is just for law enforcement.
- A lot of times a trail is often built, after it is built the ORVers and the snowmobilers will do a lot of maintaining, volunteer work.
- It is a no net gain, if you shut a trail down, it is gone, you are not going to get it back. It is an act of congress to get it back.
- “Snowmobiles, we stake our trail on top of snow. When the snow is gone you don’t even know we have been there.”

Participant #41
Household/Municipal use
- “I don’t think in this drainage it will be a problem.”
- Earlier runoff: “This is only 50 years, if you go back 300 years it might be different. I don’t think the water will be affected because you have such a huge dam.”
- More frost-free days: same
- Rapidly melting glaciers: “I think it is just snowmelt, and I don’t think the glaciers do much for water consumption.”
- Increasing minimum temperatures: “I don’t think so.”

Motorized ice and snow-based recreation
- “Environmentalists. Management, I think management more than the climate change. I do think that climate changes, but I think it is a cycle and I think we will go into a cold spell after this.”
- Earlier runoff: “Yeah your snow season will change year to year. Just like last year was an amazing year for snow, and all the way until July. This year it is sketchy still, and it is dangerous. It is being affected this year.”
- Rapidly melting glaciers: “I don’t think that the glaciers are the main feed for snowmobiling so it won’t affect that.”
- Increasing minimum temperatures: “It will affect the snow use, but that will be year to year.”
- “From a management perspective I feel that it is difficult because the more management you have the more politics that you have, so what happens is the FS is going broke. The reason why is because they do not use their resources anymore, and there are reasons why they

have done it. But, if you don't have mining or logging you don't have funding for recreation or anything, for managing it. So all of your management is getting cut, and you don't have the people to manage so the resource gets closed. The vast majority of the users are getting discriminated and alienated from using the resource because you some sort of management to handle it."

- "There are ways to handle [the cost of managing for motorized recreation] though, because the recreational users, especially the ones that have motorized vehicles, they usually have a little bit more expendable money and they are already paying some fees to help manage, it is just that the Forest Service are not utilizing the funds. Does that make sense? I think that if we had more trails open, in fact, we already pay $15 dollars per vehicle to use on federal land, and we are the only user that does, is motorized. Hikers, horses, mountain bikers don't have to pay to use the land, but we do, and that money sits in a fund and the FS isn't drawing from the fund because they didn't want to apply it. There is a two million dollar budget in Wyoming right now to use for OHVs, and that is growing by 15% every year and that fund it is not being utilized because the FS isn't applying it. If I was the FS I would be hiring a OHV manager, paying his salary to help manage to build these trails, manage these trails, because we are already paying for it but we are not getting any use out of it, and we are required to pay that fee even though it doesn't do us any service. So, it is a tough battle, the FS is in a tight spot."
- "The only thing they use the money for is to hire a law enforcement. We pay a fee that goes to a fund, and the FS applies to pay for a ATV, so they get a free ATV, and then they get to pay for an OHV ranger to manage us. Instead of using it to build new trails, to build new trailheads, to maintain trails, to maintain drainages, erosion and things like that. It is kinda sad.
- "We can't get the trails generated, a lot of these trails were existing 20 or 30 years ago, and then they closed them due to the roadless acts or grizzly reasons or whatever, and once it gets taken away it doesn't ever come back, even if the circumstances are changed, we cant get them back.
- It comes down to management, they didn't buy the resources to actually do the work to map it, so they just close it. Then again, the resources are there if they just apply for them, it takes a certain kind of rec director, and a certain kind of management philosophy to say, "ok, this is important to people." We need to apply some resources to it, and there are all kinds of volunteers and funding available. I can't go and apply for a grant to get money to go and fix that trail, or to reopen it, or to map it, or whatever."

Participant #42
Water Quality

- "Well, development along the highway to Yellowstone would be one of the things that could certainly impact that. Poorly installed sewage lagoons, not good monitoring of wastewater, graywater that comes out of the lodges up there. Then you have the runoff from the snow when they plow the roads and stuff like that that gets into the streams. Those are all part of what I think could impact that up there, could directly affect it."
- Earlier runoff: "I do not think so."
- More frost-free days: "yes, I think it could if this is a warming trend that is going to continue, and not a cycle. Certainly could, it would impact the amount of snowpack that

falls, it would impact how it goes into the ground, runs off the mountains, and it depends on how rapidly all of that happens."

- Rapidly melting glaciers: "It is the same deal, sunlight glacier up here is growing. There are certain places that they are growing. But if the glaciers do melt, then it certainly impacts my business tremendously. Because those feed back into the system later in the year and keep the temperatures down, and keep the groundwater charged, that kind of thing. If we lose the glaciers we lose the ability to wet the ground, or sub-irrigate like we used to be able to do."
- Increasing minimum temperatures: "Well, certainly it goes back to how quickly the snow melts, and whether it can stay up there in the form of snowpack or whether it snows and just runs right off. I think a lot of that is impacted. Personally, I think a lot of this is cyclical stuff, two hundred years to three hundred years we haven't really run out the numbers on that because we are all freaked out about global warming right now. But I truthfully believe that if went back in time, like around 250 years ago, volcanic activity was going on, we saw that winter for about 10 years, and it could be tied to events that nobody is paying attention to. Volcanics, and earthquakes and things like that, but if we are going to see this minimum temperatures increased then we could see long term impacts from that."

Education, management and science

- "Well, I think getting our managers, whether they are with the state or the Federal USFWS to come on board with up to date management practices, not things that are 50 years old, "like lets just throw more fish in there if we have a problem." They need to study it, they need to manage it and they need to make decisions based within the system. Not because somebody wants to catch 6 fish or take 12 bull elk, whatever the case may be. They just need to be better at that, and I think if they were not involved in bureaucracies then I think they probably could make those kind of management decisions. They need to be able to adapt and improvise, instead of studying things to death. We cannot even put the 1988 land use plan into effect because of litigation, so what is the point of doing more. If you are going to get sued, it is kind of counter productive. Then they start righting EIS and EAs geared to these people because they know they are going to get sued. It is not right, it should be based on the resource. It doesn't have anything to do that you want your house made out of redwood in the forest, or I don't want you to have one."
- Earlier runoff: "I think that is tied to the 365 day model, not a June model. All you need is one warm rain to skew your curve, so I do not think that is an important issue."

Participant #43

Hydropower

- "I guess it would be based strictly on snowpack, in years where there have been low snowpack we have not been able to generate as much power. In years where there is a good snowpack, above average and record levels we have been able to generate and provide that benefit to the public."
- Earlier runoff: "It shouldn't, or if it did it would be minimal, only because we can store the water with the dam."
- More frost-free days: "I do not know."

- Rapidly melting glaciers: "Not to my knowledge, you know so much of what we get, the water we use to generate hydropower is every year snowpack, but I don't think the glaciers have any impact on that."
- Increasing minimum temperatures: "You know it is possible that this would affect hydropower, because if you snowpack melted earlier it might have an affect on how you stored water, or how much and it may, you may have to alter your operations."

Recreation/leisure activities done near water

- "Actually no, I think some years might be a little better than others, but I think it is always going to be there, if that makes sense."
- Earlier runoff: "Not at this point, I think if it got worse it may affect. You know four days isn't that much, but if it was weeks or month then possibly."
- More frost-free days; "No, other than it might just shift the season when you are out doing those activities."
- Rapidly melting glaciers: "You know, if people are going out just to see the glaciers or wildlife associated with them, or hiking or camping near those then sure I think there would be an impact."
- Increasing minimum temperatures: "It might alter when people go or how often they go, sure."

"The Bureau had transmission and generation, and president Carter created the DOE and he kind of split the bureau in half from what I understand. DOE and WAPA took the distribution and marketing side of it, so once it leaves our transformers then it becomes WAPA. Its my understanding that it feeds into the grid and serves Montana, Wyoming, and Colorado. Western markets that to some of the rural electric associations, and I believe some of the other like tristate which is a big one down in Colorado. But is hydro cheaper than some of the other forms, I do not know. I guess there are some economies of scale, the primary purpose of the plants here are to generate what power we can to meet irrigation demands. We generate both at Boysen and Buffalo Bill, but that same water is used at Yellowtail. So, I don't know how you capture that benefit, but it keeps getting used over and over.

Participant #44

Water quality

- "Primarily development. The oil and gas drilling in the forest lands, recreation, heavy recreation use, motorized recreation use, and non-motorized too. I see impaired stream throughout the forest, and off the forest, and all sides want to blame it on everyone else but it is contributing all the factors. I have trails in the forest that horses have just chewed the crap out of, and there hasn't been a motorized vehicle on them ever. It doesn't matter who is to blame, it is just limiting factor, and without the water quality I do not see where we have much to build off of."
- Earlier runoff: "Not so much to receive high quality water. Again timing plays a role in everything with the agricultural set up, and this whole area is based on timing. If we do not have reservoir storage to catch earlier runoff then we don't have that space available, then we miss that opportunity and the storage and management of the water. With management we could get along, with proper management and having a space to put that water in. I do not know how much climate change, or the affects of climate change with the beetle kill and things like that."

- More frost-free days: "It could, it always will have an affect, but it may be a positive affect too. It will change cropping patterns, and what crops will grow. We could go from a zone 3 to a zone 4, because of that and different crops could be grown in this area."
- Rapidly melting glaciers: "It does, actually it impacts the quantity tremendously. We receive a lot of our late season water from those glaciers, and we can tell when it stops in the fall. It is relied upon, and again it drives everything we do in this area because it is part of our water supply and everything is based back on that water supply."
- Increasing minimum temperatures: "Sure could. Not know all of what the affects could be, but I could imagine that the ground may not freeze in the fall prior to snowfall and if it is insulated through the year then that changes the way the filtration works in the spring when runoff does come. The myriad of changes that could occur with just a little bump in temperature is huge, and we do not know what all those changes could be, and things could be changes and we don't even recognize at this point, but it could be leading to problems down the road that we do not foresee. That could be causes some of the little things that we do see like the beetles.

Preservation of landscapes, livelihoods and lifestyles

- "Well, I think it actually bases off the quality. Because of the quality of water and the quantity that has been supplied off the forest, and historically livelihoods have been developed. Agricultural communities, everything we do, the reason we live where we do is because of the water running off the mountains. Being a headwater state that is just the nature of the beast. And so, these communities to thrive and continue to thrive where they are and how they are set up is based on that supply of good quality of water, and the quantities necessary to continue to come off those forest lands."

Participant #45

Gradual discharge of stored water

- "Mother nature. You know if we don't have any snowfall in the winter or rain in the summer then we have a lack of water for all of these other purposes that we talked about. That is why I think that is the most important."
- Earlier runoff: "Sure, it wouldn't be gradual anymore it would be rapid."
- More frost-free days: "I guess it could affect the gradual discharge in a way, because it wouldn't be so gradual."
- Rapidly melting glaciers: "Sure."
- Increasing minimum temperatures: "Sure."

Commercial Irrigation

- "Obviously if there isn't enough stored water in the mountains then those of us that depend on irrigation to produce crops and water for livestock would have to reduce our income basically, because that is how most of us make our income is through agriculture in this area."
- Earlier runoff: "Yes it could, but most of the irrigation water is stored, and people seem to be able to predict, they will use the amount of snow received in the winter time and predict how much they will have to lower the reservoirs before they start the irrigation season. So they have a set number of cubic feet that they keep in those reservoirs for irrigation purposes. I think that if there was an earlier runoff then I think it could still be controlled.

Then again, we have problems like we did the last couple of years where we had too rapid a runoff and we had flooding. It that case definitely it would affect irrigation."
- More frost-free days: "If that is in fact the case, I think it is something that in a way could be a benefit to agriculture if you had more frost free days."
- Rapidly melting glaciers: "Sure."
- Increasing minimum temperatures: "Sure because there again, over time if you have an increase in temperature then your glaciers would probably be melting. I think that if that were in fact to happen then it would affect these two things, as well as everything else."

Participant #46
Household/Municipal water
- "I guess, personally I live in the city limits here and so our household water is dependent on stream flows, and/or they also have groundwater. But a lot of the municipal water is derived from the watershed here, so I guess that for me and my family that is important. If you don't have water, you don't have much, so a good source, a good clean source, a good quantity."
- Earlier runoff: "I do not know if it would affect it either way."
- More frost-free days: "Potentially, there would be more need earlier for, again more vegetation if there is a longer growing season, those kind of things. Just the demand on the vegetation I guess might affect the overall discharge or what might end up getting this far down the system anyway."
- Rapidly melting glaciers: "I think there again, if, maybe long term if that is the case. If the glaciers continue to, or is it just a snapshot in time. I don't know. I am not 100 percent sold on this whole theory."
- Increasing minimum temperatures: "Yes, I think it would potentially over time decrease our overland flows that are potential for your historical drink flows, so that could affect quantity of water."

Water Quality
- "I guess just a healthy landscape, hopefully. If the watershed is well managed and there is adequate vegetation or a natural filtering system that will prolong good clean water, I guess is my look at it."
- Earlier runoff: "It might affect it a little bit because maybe that vegetation hasn't had a chance to green up, and so maybe the vegetation would be further along I guess it might affect the stabilizing of banks or the filtering of runoff. There could be a disadvantage if there was a little earlier runoff."
- More frost-free days: "Well, yeah I am not sure how that would affect that."
- Increasing minimum temperatures: "I assume it could probably affect the water quality in a negative way too."

Participant #47
Household/Municipal Water
- "A lot of what tribes and we are concerned about more than anything is what is coming over the mountain. The reservation is a class one watershed, and you have got Jona Field. The pinefill area and the big gas play over there, two to three thousand wells and what falls out of a lot of the pollution that comes over the mountain. We get a lot of acid rain, and the

Wind River mountains don’t buffer a lot of those pollutants very well because they are so rocky and glacial, so it doesn’t really buffer a lot of those contaminants. I think they are seeing a lot of our high mountain lakes are getting, there water quality is not as good as it used to be because of what is coming over the mountain. The tribes and us we cant say a lot about of it, we just have to be down wind from a lot of the pollution. That affects a lot of the water that comes out of the mountains comes down, and of course it affects the groundwater. If it hasn’t yet, it will affect it sooner or later. Our utilities that serve water to the communities, both of them are right here on this river that comes by Fort Washakie. We got an outtake up here, and one down at Ethete. As far as municipal water facilities we rely on good water that comes out of the mountain. To me that is a priority, especially when we got more Indians moving back to the reservation. Driving around you see a lot of houses, and home sites. There are just a lot of people moving back to the res, one is for the benefits that the res has for enrolled members of the tribe.”

- Earlier runoff: “No.”
- More frost-free days: “Probably not.”
- Rapidly melting glaciers: “Not, no.”
- Increasing minimum temperatures: “It would affect the amount of water available because our systems can only deliver so much water, and when it is warmer out people use more water. So they put on water restrictions.”

Commercial Irrigation

- “We have 1.85 million acres of range land on the reservation and 50,000 acres of irrigated land, and a lot of people that use those land rely on good irrigation water. Not only good water quality, but good amounts of water to irrigate with. A lot of people rely on that for a living.”
- Earlier runoff: “If we have earlier runoff then we don’t have the ability to store late irrigation water, so when we get the early runoff it just runs out down the river and off the res, so it will definitely affect irrigation.”
- More frost-free days: “It would affect a longer growing season for irrigation, which would probably benefit agriculture.”
- Rapidly melting glaciers: “It would have the ability for irrigation water because about 10,000 acres of our irrigated land relies on Dinwoody Glacier for late season irrigation.”
- Increasing minimum temperatures: “It would affect it definitely, I guess one benefit the plants would probably grow better; you would probably get more hay, but as far as the amount of irrigation water it would probably evaporate more so there would not be as much later on in irrigation season.”

Participant #48
Water Quality

- “Affecting it, probably across the mountain from all of the development, just the development. I can’t remember what is across the mountain, but all the way over into Idaho. Just from all of the refineries, or I can’t remember what is on the other side of the mountain but just the development and all the stuff that could come from the rain, has a huge affect on our water. If there was development in the mountains could deteriorate the quality of the water.”
- Earlier runoff: “I do not think so.”

- More frost-free days: “Not significantly.”
- Rapidly melting glaciers: “Definitely, it was a few years ago when it melted a lot and a big chunk fell off, and the water was milky, a different color, it was more white and grey.”
- Increasing minimum temperatures: “Yeah.”

Native American Cultural and Spiritual Values

- “Just people not respecting it basically. The use of it, and it kind of goes back to water quality. If we were to build a ski resort up there, or houses up there, build something next to the river or inside the river to damage the watershed.”
- Earlier runoff: “No.”
- More frost-free days: “No.”
- Rapidly melting glaciers: “No.”
- Increasing minimum temperatures: “No.”

Participant #49
Household/Municipal Water

- “Mining, and the oil and gases because like where I live in the Pavilion area is getting affecting because of the oil being distributed in the water. I do not know if our groundwater is getting that way because every once in a while you will smell that gas odor through the system. We have got ours tested so many times, they do not have; it is going to affect a lot of people and their drinking water.”
- Earlier runoff: “I would think so because of the earth shifting. Yeah. Especially because it causes a lot of flooding too, and they haven’t had this much flooding. The flooding is coming earlier, and then we have the lack of water after the flooding and the runoff. Later in the summer, towards August and September the rivers are down and they are really low.”
- More frost-free days: “Oh yeah”
- Rapidly melting glaciers: “Oh yeah it will affect everything.”
- Increasing minimum temperatures: “I would think so, but then again not really. Depending on the year and what cycle we are through.”

Native American Cultural and Spiritual Values

- “If we do not have the water resources to do a lot of stuff that we do for our culture. Even though they fought for their water, it doesn’t mean that it is going to be any good.”
- More frost-free days: “Oh yeah.”
- Rapidly melting glaciers: Same as above

Participant #50
In-stream flow

- “With in stream flow I think of streams that are flowing as close to possible to their natural hydrology, so that would provide a lot of biological benefits; fisheries, wildlife, irrigation, agriculture to a certain extent if there is enough water. However, it is also threatened by things like irrigation and agriculture. We lose some of these streams that run dry, and then you lose that water quality. Water quality is threatened and then the biological diversity is threatened, and even the human use of that stream is threatened. So when I think of in-stream flow, I think of basically a full healthy stream that can move its water and move its sediment and maintain its morphology and not degrade. Not have the bed level of the channel go down or go up, there are not watersheds in Wyoming that really have their complete natural hydrology, there are some and a lot of them are on the Forest. The ones that are entirely on the Forest like the Greys River, although that is on the BT not on the Shoshone, but I just think of in-stream flow, I think of full healthy streams in kind of a simplistic way. And luckily there is a law that allows in-stream flow rights for certain streams, but those water rights are so junior to the other rights on the streams. Old diversions threaten it."

- Earlier runoff: "The timing of the runoff, lets see, yes in terms of I see a threat to maybe some of those streams functioning well in the September/October months. There is still a lot of fish activity and there is spawning, and if an early runoff means decreased flow in September/October, then yes the in-stream flows will be decreased and the water quality is threatened, but I still have to preface that sentence with if. If an early runoff means a dry channel later, then yes those are threatened, but I guess I would have to respect a study that would have to demonstrate that an early flow meant a decreased baseline. It is not the earliness of the flow that concerns me the most, it is the decrease in flow or the loss of glacial storage. That is probably what threatens these the most."
- More frost-free days: "I keep thinking about pests and beetles and stuff when I think about frost. I guess that I cannot say, it is hard for me to say yes to that, unless I drew a link because it ties into three a little bit. I guess that I cannot say yes to that one."
- Rapidly melting glaciers: "Definitely those two."
- Increasing minimum temperatures: "I would say yes, if these are research based questions so my answer would have to have a research based answers which I do not really have. I guess this ties into number 2, but if there was scientific data that indicated that this influenced rising stream temperatures then yes definitely, because once our stream temperatures are warmer it relates to this because of evaporative loss, when our stream temperatures are warmer, our dissolved oxygen is lower and our fisheries are stressed because dissolved gases stay in solution better in colder water. But I would have to preface that with an if, because I would have to respect the research to make that link, and we have not taken our data sets and tried to make that link, but I would be curious about that. What is hard, is the last five or six years has been a serious drought, so our stream fllows have been low and we have had some really warm waters, and it is a huge stress on the trout. So I would have to say yes, if we are losing that minimum temperature I would surmise that our stream temperatures are increasing to a certain extent. I do not know when in the year, or when in the hydrograph but these warm waters are bad for both of these. Especially since so much of our stored waters are in reservoirs, which are like big evaporation ponds, so which creates salty water too."

Water Quality

- "Some of these systems that are pristine and natural by themselves are pretty rare, provide so much more benefit to population of our fish and wildlife because there is just minimal health threats. But for water quality threats it is interesting because there are things that are actually chemical threats, you know if oil threats or industry, or storm water runoff of some of our towns is harsh enough; yeah we either have fish kills or water that is bad for livestock, various water quality threats, or we have e-coli that is bad enough for human contact. Then there is sort of this silent, not silent, but in the last decade it has become pretty clear that there is issues of water quality that are not really chemical threats but there is just levels of sediment, and silts and sands that are, there is a natural component to that, but human stresses has accelerate that erosional rate and we are seeing sort of cloudier streams, and those waters have, they are not as good for site feeding fish, they silt in a lot of headgates, there is this threat of excessive siltation, and it is water quality to the extent that it is in the water column, it is part of the stream, it is not like your mercury or lead or something that really prompted the Clean Water Act to start with. But it is still a general threat, and it leads to degradation. So there, the human stretch there is probably stream degradation through over grazing or channel change, or improperly placed culverts, or head cuts, or minimizing riparian zone with that can stress the stream physically. For chemical threats it is storm water, oil field or industrial activity, some mining, that is sort of what we see with the data that we look at and I see as a citizen. On the Forest, luckily the industrial pressure is not as high, but there is still some areas. Well, beetle kill will be interesting, to the extent that you call that human is obviously debatable, but there is going to be some elevated erosional rates in the next few years, as we lose all those trees and those big expanses are exposed. However, it seems like where I see dead beetle kill I see a lot of young trees coming up so that is promising, kind of holding that soil level together. I know that is a big deal for the Forest Service now, all those trees falling over on campsites."

Participant #51
In-stream flow (Unprompted mention of climate change)

- "The thing we worry about most for in-stream flow would be the development of it for commercial or agricultural interests, potentially residential. But also the climate uncertainties will have a large impact on that."
- Earlier runoff: "It could, it would affect it the most later in the year when the water demand is at its highest point. If there is an early, quick runoff then the late season storage that we see from both glaciers and snowpack is going to impact the amount of stream flow at the end of the year."
- More frost-free days: "I agree, yeah I think so, I think it will be the same impacts of less water storage, water coming down quicker, and I think that if this kind of going towards the pine beetle thing and the impact that it is going to have on that, then I think that it will also have an impact on stream flow by reducing the amount of water stored in trees and the amount of sediment that is going to be washed down in the system without them."
- Rapidly melting glaciers: "Yeah absolutely, especially in the long term."
- Increasing minimum temperatures: "Yeah, I think anything that is temperature is going to affect the amount of stream flow, particularly late season when we worry about it the most, and anything tied with glacier will be a direct impact."

Conservation of keystone species (Unprompted mention of climate change)

- "I think it will be a little more of the same, any kind of development or just misuse of the resource, and then again, depending on what species you are talking about, the climate uncertainties are going to have an impact on that, particularly we have got cutthroat in mind for sure."
- Earlier runoff: "I think that it kind of ties into the stream flow stuff for what we focus on, I think the same thing either a reduced amount of stream flow or increased temperatures in water will affect the conservation of a lot of the aquatic species that we have."

- More frost-free days: "Anything that is going to be temperature dependant, which would be water quality and the pine beetles, and stuff like that, I think this will have an affect on that, yeah."
- Rapidly melting glaciers: "Yeah."

Participant #52
Water quality and Native American cultural and spiritual values

- Cultural values will be impacted by denying access to the resource on the forest, and by allowing activities without due consideration for the resource. Especially special roots, trees, and herbs that are important. Access and other activities can affect the utilization of very important spiritual and protective aspects of the plants and resources on the forest.
- The resources need to managed on a watershed basis, and there needs to be an understanding of the basis of impacts on specific watersheds.
- There needs to be work between federal agencies, NGO's and tribes.
- The tribes need to take advantage of their unique legal and political relationships with the federal government.
- Climate change will absolutely threaten these benefits. "Yes, you bet." Water storage and water usage, and allocation must be in tune with global warming and climate change.
- "Water impacts everything that we ever going to do. Lots of us here for awhile have seen it, and in ten years it is going to be too late."

Participant #53
Water Quality

- "You know just thinking upstream from here, it is like it has a pretty pure source and that is one of the reasons that I live here is because the water is coming right out of the mountains. So there is not a lot of adverse impacts to it, I mean there is just our water treatment plant, I mean that stuff is a little chlorinee, sometimes I feel like you could probably just dip a cup in the water and drink it. When I think of water quality I think of drinkability and the ability of it to maintain fish populations. There is not a lot of stuff going on upstream that is very bad."
- Earlier runoff: "More quantity, you know what I am saying? I do not think that when water is coming off the mountain the quality of it is changing that much."
- More frost-free days: "I cant think of frost free days affecting water quality."
- Rapidly melting glaciers: "I cannot think of how."
- Increasing minimum temperatures: "I do not think warming temperatures will affect water quality. I am trying to think of ways. So you have more beetle kill, so you have a watershed that is more prone to erosion perhaps, so that could affect the quality of the water. But the way that the Middle runs, it percolates through so much limestone by the time it gets here it is just clean. I just cant imagine the natural processes will be able to overwhelm that."

Household/Municipal Water

- "I guess it sort of just water for household use, and really when I think about it the only real threat that comes to mind is the robustness of our municipal water system. It is not unusual for a main to break, and then you do not know if you are going to have water. They seem to be pretty responsive to that, but in a flood situation we have certainly, a couple years ago and we were down for quite a while, and we had a hard time dealing with the water and there were questions about potability. I think the biggest threat would be the ability for municipality and the county to respond to water crisis."

- Earlier runoff: "Certainly like water is coming off faster and we have sort of a small reservoir system that feeds into the middle fork and that reservoir system has been stressed in the past. I certainly think that if we have another extended drought situation like we had not that long ago, and if stringent measures are taken then we could be in potential water crisis in August or September. We are not getting our water from a steady reservoir source, there are small reservoirs, so yeah it would affect our ability to use water for things that we really like to use it for at our house."
- Rapidly melting glaciers: "Obviously the availability of water would be the main concern. I have seen some studies that point out what portion of your annual runoff is coming from glaciers, which is not going to be your annual snowfall. It is the long term ice that is up there, so yeah obviously in a warming world with shrinking glaciers we are going to have a more and more diminished water supply."
- Increasing minimum temperatures: "I mean on one hand, once it gets cold enough it does not snow. It is possible that and average minimum temperature that is lower could increase precipitation in the mountains, so we could get more water from that. I think that does not speak about water quality, it speaks to municipal supply. I think the jury is still out on how warming temperatures will affect water supplies."

Participant #54
Water Quality

- "The first thing that comes to mind is the Maverick that dumps all of there wastewater into the river right across from my house. Well I guess it is not their wastewater, but all of the runoff that comes from the gas pumps and all of the trucks that sit there, and all of the oil and sediment in that parking lot goes straight into a pipe that runs straight into the middle fork, so that is the first thing that comes to mind but that is just because I see that all of time. The other things are sort of the less right across the street, and it just poor water treatment, especially in the west, excessive use of water for agriculture, which obviously they are all competing interests, we need the food to some degree, but I guess it would be misuse."
- Earlier runoff: "The thing that comes to mind is the flood that happened two years ago, and that was a combination of late runoff because it had been a really cold spring, so we had a quick warm-up and a bunch of spring storms. And so, creating climate changes more than just earlier runoffs, and just those things creating things that the municipality might not be able to handle in terms of keeping the water supply."
- More frost-free days: "I think it goes back to the quantity issue, like I would not be so worried about the quality issue with frost free days. Just it messing with the water reserves in the mountains, and how bad it is affected long term. I would expect there to be some stress in the system from that, and not that I can foresee what it would be."
- Rapidly melting glaciers: "I think my answer would be the same for my previous one, and these are interconnected factors and we are changing things in ways we do not understand with climate change. What I have read, and my gut says is probably true is that we are probably going to hit some kind of tipping point where things are changing a lot faster and we do not have an understanding of how that is going to happen. I think there are things that we are not predicting, and glaciers certainly play a big part in that."

Household/Municipal Water

- "The answer feels sort of the same, just in terms of water being such a hot topic and such a rare resource in the West. I mean professionally we talk about the proposed Million Pipeline and all of our water resources being valuable and pilfered to some degree, so that feels like the biggest threat to me."
- Increasing minimum temperatures: "I feel like I have the same answers for all of these."

Participant #55
Water Quality

- "Certainly negatively, I guess starting off there, obviously any kind of pollution whether that comes from around here a lot of livestock grazing occurs along stream courses and river courses, there is a lot of feces that ends up in the water. So I would say potentially livestock grazing, wildlife can too, but not to the same degree that livestock would. Any kind of oil and gas discharge, we see that pretty commonly on the reservation and off the reservation too that a lot of the effluent that is coming out of these small oil and gas fields around here can be pretty ugly looking water, even though they have got the permits to do it, it is still a concern. So oil and gas, and I guess manufacturing too, say like the sulfur plant in Riverton is another potential, and is polluting the Wind River, Rec has done some work with that. The sulfur manufacturing plant there in Riverton is another issue. Any kind of roadway discharge potentially could be a pollution source. Things that could positively affect water quality, any kind of healthy riparian habitat is really key that acts as a filtering mechanisms, beaver ponds, wetlands, marshes, any of those kinds of habitats are beneficial, so they are important for providing good water quality."
- Earlier runoff: "Definitely for those two. Runoff occurring at different times could certainly affect water quality, and if runoff comes, if it is not a protracted runoff and it is more of a flushing event, and I forgot to mention water quality, yeah I am thinking too something else that comes to mind is climate change affecting the loss of conifers from beetle kill and we do not know how that will affect water quality but the assumption is that if you lose your tree cover and if understory doesn't grow back in there you potential could have a lot more sedimentation occurring and so that would definitely be a factor affecting water quality too."
- More frost-free days: "Not sure"
- Rapidly melting glaciers: "Definitely"
- Increasing minimum temperatures: "Definitely"

Conservation of keystone species (Unprompted mention of climate change)

- "Certainly climate change factors into that. That is kind of the big thing when I saw that, and the impacts that it has on water and then the trickle down affect that is has on these particular species like whitebark pine, and any of the species you mention cutthroat trout. Everything, the entire ecosystem. So that is kind of the elephant in the room so to speak I guess that comes to mind affecting keystone species. You know, we do not know how that is going to play out here, nobody really does. I mean you indicate that it is going to get drier here by all indications, so that is what we are thinking. Then how you go about trying to keep those ecosystems together in the face of climate change, we are all struggling with that. Well, I guess trying to think of in light of climate change there is some effort to do some cloud seeding here in the last few years. That, if the trend is less snowpack, and if the cloud seeding does appear to work that would be a beneficial thing to some of these higher elevation species that we are thinking of, like whitebark pine and so on. Just increasing snowpack and that sort of thing, not only for keystone species but for water delivery later in the summer for irrigators and municipal water supply. There has been a pilot study I think around the last four or five years, where these machines, I do not know how much of a pollutant it is, I do not know a lot about it, but they pump silver ions of some sort into the atmosphere and they are used as the nuclei that these particulates are in the atmosphere and that is what clouds need in order to coalesce to that nuclei and then eventually it creates a snowflake. The thinking is that it will actually create snowfall, and they are doing that around the state, and they are trying to see if it does make any difference."

- Earlier runoff: "Runoff could affect keystone species."
- More frost-free days: "Not sure."
- Rapidly melting glaciers: "Definitely"
- Increasing minimum temperatures: "Definitely"

Participant #56
Lake/Reservoir Recreation

- "I see the factors on the SNF are driven by the health of the trees. We have a huge issue out there right now with the mountain pine beetle with all of the dead trees. The way that would have a major affect on lake recreation for example, if we have major fires in some of the larger watersheds there could be a lot of debris issues, and also timing issues about when the water comes down without healthy growing trees the water flushes out much quicker. That can be an issue with flooding and lakes overflowing, and trees and roots and limbs end up in the lake and that is a big safety hazard. So that is what I see as the major impacts of it, or course that carries over into water quality and all kinds of other things."
- Earlier runoff: yes
- Increasing minimum temperatures: "It certainly could because reservoirs depend primarily on snowmelt and runoff, if we have a warmer and drier trend that could result in less water in the reservoir and reduced levels and that can make a big difference in the quality of the recreation. If the water levels are really low there is a lot more hazards, of course warmer could be a good thing, Wyoming doesn't have a lot of warm days."

Motorized Ice/snow based recreation

- "I do not know that it would affect the motorized snowmobile type activities as much, it does have an affect on trails. The fact that a large number of dead trees tend to blow over and block the trails, and that is an impact. There are always concerns about temporary closures for access that shouldn't really affect the snowmobiling too much, but sometime it does and sometime it is not totally logical. That kind of thing."
- Earlier runoff: "It might shorten the season a little bit at the end, but primarily I do not think it would be an affect. As far as climate change if what they are predicting really pans out and we get warmer and drier that could definitely have an affect because we would have less snow later in the year in a shorter amount of time. Given what they think is going to happen really happens it would have a big affect. We are seeing a lot of fluctuations in snowpack right now, compared to more of an average and I think climate change is an issue, and it is real, it has always been there. I don't think it is as predictable as people say, so I do not know if it going to get warmer and drier like they say or maybe cooler and wetter, and it is

very difficult to tie to a small piece of ground. Even a 3 million acre piece in a global whether pattern situation is pretty insignificant."

Participant #57
Water Quality

- "Quality wise I would like to see that it doesn't endanger the physical body, so that the quality of water is clean and refreshing. At this time, probably the my understanding the state did a cloud seeding process and so some of that might have floated down through the glacier system and the lakes causing the silicates to get into the water and contaminate. Forest fires are another one where the charcoal kind of goes through the ground water and filters through, and sometimes you see that within the house water gets dirty around the spring time, but again it is back to the filtration system that people have."
- Earlier runoff: "yes, because gravity pulls it faster and so again you are back to square one, waiting for the stream to slow and be able to cause growth factors for algae and other things to grow because the swiftness of the water just carries everything beyond, and so growth happens after the runoff."
- More frost-free days: "About half and half, because again the frost days would depend on whether it was a warming day during those two days or something I would say, because not every day is the same."
- Rapidly melting glaciers: "I would say yes because if there isn't any glacial pack there then we wouldn't receive any."
- Increasing minimum temperatures: "Not to a high degree, no."

Native American Cultural and Spiritual Values

- "I would like to see a little less pulling away from the water streams because when they start to lower the water quality and the water levels on streams it does make an affect on cultural plants growing at a proper rate, because the less water you see throughout the summer then some plants only have a certain amount of time to grow. And in our area we have a 90 day growth period next to the mountain where the lower regions have a 120 days, and so if they are going to lower the water we have less water for the plants and so that causes a shortness of growth for our natural plants that we use culturally."
- Earlier runoff: "Yes, due to the fact that some of it has to pertain back to again the plants, but within time seasons of culture and when spiritual practices are done they are in four seasons and so some of it has to deal with during the cold times, during the summer, spring and fall and so each area has a different runoff process."
- Rapidly melting glaciers: "It would be detrimental to the culture because what feeds the system is the major glacial area."
- Increasing minimum temperatures: above

Participant #58
Glacier-based services

- "Probably the pollution that is in the air, there is some coming from Red Desert area just outside of Green River I think it is by Rock Springs. They are producing a lot of fumes coming from generators and motors, and the gas plants just on the other side of the Rocky Mountains and its affecting the glaciers. One of the others things is cloud seeding, the State of Wyoming is doing some cloud seeding on the Shoshone Forest, I think one of the areas they are doing. I think one of the issues we had in our department is there is a correlation in the cloud seeding and the flood that just happened recently. We have a person that studies bugs, and he did some studies and he found that correlation and we did explain it to the state of Wyoming, that you are causing problems with this cloud seeding. Plus they did not get permission from the tribes to do it, and they are doing it on the borders of the reservation so they are affecting our water, our water quality and what we are finding out, I think it is the silver nitrate that they use that has a major affect on the plankton that is in the high river, high lake, mountain lakes and most of the fish up there they eat this plankton, and that silver nitrate is killing off the plankton which means the fish don't have anything to eat, so we are very concerned about that. Plus the glaciers I think right now we just some of the research that we did I think was um, we did some high water sampling of Baptiste lake, and some of the glaciers are gone, the ones that used to be up there for years and years are now gone, or slowly disappearing, and so that is one of the things that we are looking at. The major flooding is causing a lot of erosion around the rivers where the trees are growing, most of these trees are being knocked down and now some of these trees cannot support the soils around the rivers. It is really causing major problems and cutbanks rivers, washing out cultural areas that we Indian people here do keep as cultural areas, those are being wiped out right now. I think one of the things is the global warming, but there is a lot discussion into that and there is a lot of controversy, but I do understand that there are some areas up around the arctic were some of the glaciers are receding pretty quick and they are finding prehistoric sites that is being uncovered right now, and they are finding arrowheads, and arrows, and all the activities of the old prehistoric people that were here a long time ago. I don't know if that is good or bad, but it does raise concern. Just how fast are these glaciers receding, or just how fast are they melting."

- Earlier runoff: "Sure."
- More frost-free days: "Yes"
- Rapidly melting glaciers: "yes"
- Increasing minimum temperatures: "It does have an affect"

Native American Cultural and Spiritual values

- "The water quality. According to one of our elders, one of our elders did mention that all of the sicknesses that the tribes now have today: diabetes, all kinds of cancers, skin conditions, blue babies. Some of this water that is used by the tribes today through these towns like Fort Washakie, and Ethete go through our treatment plant. What that treatment plant is doing is killing all the little microbes and little tiny planktons that used to be in the water that tribes used to drink a long long time ago, and according to some of our elders they said that when the people a long time ago used to drink this water they were becoming immune to all kinds of diseases, but the young people today cannot even drink any of the water up there. They take one taste and they are sick, it could possibly kill them, but the elders today can go up there and drink water and it wont affect them whatsoever. That is one of the things that came out, I think the major disease that we have is diabetes, and I think that is one of the reasons that all of the water is contributing to that. It is not scientific, but tribal people usually to me in my own experience are pretty well knowledgable and experienced in those areas, and I think that is one of the things that the white culture don't really take into account. Most of the theories and all of the conclusions they come to is scientific, but they never look at the cultural part of the traditional peoples. It is one of the reasons that water is very important. Water is very important to the people, it is one of the main life giving resources that is on the Reservation, throughout the whole world, if it wasn't for water we would not be existing. Water, on my own side, personal views, religious and ceremonial are those ones that we need to keep up, and that is what distinguishes us from other races is that we do have a culture that is keeping us sustained and alive, and once we start losing that we mine as well just be like any of the number, because the main society in the United States everybody is a number, it doesn't make any difference if your number is wiped out or not, it don't make any difference. But it is the cultural ways we are all, you lose one you lose a major part of the tribe and it is one of the things that I think the main society don't see. Once you lose a very important person in a tribe, you lose a very important resource, a source, so that is one of the things with the culture. Spiritual, everything has got a spirit, according to the tribal people, everything has got a spirit. The rocks you stand on, the soil you stand on, the water you drink, the air you breath, the sun, the moon, the owls, the wildlife, even the air that you breath, it has got a spiritual value in it. It is one of the things that the majority of people don't see, is that the spirit isn't a God. It isn't like in some societies you put a God to different things, like this is a water god, that's a soil god, that is just a god god, you know? Ours is just, all within, together, it is all within one society, and it makes up one society, and all of these little beings and little plants, and all these rocks, and the water is all together. We are all one community, and once you start destroying parts of it, you are destroying yourself. It is one of the things we look at in a spiritual way, it is like looking at the sun. Each morning we pray to the sun, because the spirit gives us another day to survive to live another day. I think there is misinterpretation from the majority of societies that we see the sun as a god, it is not. It is part of our life, and the sun is part of our society and then we pray that this sun is given us another life to live. So that is one of the ways that we see it."

- Earlier runoff: "Um hum"
- More frost-free days: "Yes."
- Rapidly melting glaciers: "Sure."
- Increasing minimum temperatures: "It does affect."

Participant #59
Hydropower

- "I see the snowpack diminishing yearly, we do not have quite the snowpack, and um, you know the water where the hydropower is in Boysen that lake sometimes during the late fall it is half empty, and one of these years it could be even worse than that, it could run plum out."
- Earlier runoff: "Yeah, because it runs off sooner and the summer is longer, and the evaporation and whatnot is gonna cause less water to wear the hydropower is going to be."
- More frost-free days: "you know I am not sure about that, I am sure that it would do something. Yeah, I am not sure."
- Rapidly melting glaciers: "I believe so, the sooner they are gone the less water we are going to receive."
- Increasing minimum temperatures: "Yeah I am sure it would somewhere along the line, I am not sure how but I think it would. For both of them, if it warming up sooner, you know

you are going to end up, if you do have frost it is gonna runoff and you are not going to get nothing soaking into the ground."

Household/municipal use

- "Ground contamination of water. Ok, out here the Pavilion they are seeing a lot of contaminated groundwater, and they do not know what it is caused from whether it is fracking or if something else is going on, and that could happen all over for the groundwater."
- Earlier runoff: "Maybe in some areas, some not, depending I guess where you are located. If you are way out in a desert type area, yeah."
- More frost-free days: "Not sure."
- Rapidly melting glaciers: "Well, yeah I guess if the streams get low then your groundwater is also going to get lower."

Participant #60
Water Quality

- "Well, it is some of these over here at the other end. It is the, I think, the use or misuse or overuse of the resource can impact, and particularly when we are talking about public lands, national forest lands in particular they are multiple use unless you are in the Wilderness and even then there are still some uses going on. And, a lot of those uses unless they are pretty low impact, such as fishing and hunting and hiking, and backpacking and stuff like that. Those are the low impact ones. A lot of those use can impact negatively the water quality. The water quality would impact too, well global warming besides the glaciers going away, I mean that could impact water quality directly if there is a lot of till coming in from the glaciers and all that sort of thing as they gradually melt and recede and whatever, but on top of that just having less water in the stream that can add to, if you have the same number of livestock or wildlife or whatever utilizing a stream with less water available that can increase the chances of negatively affecting the water quality."
- Earlier runoff: "Yeah. I cant tell you definitively, and maybe there is an answer that I do not know. Obviously if you have earlier runoff, then you are going to have dirtier water earlier in the year, of course it could clear up earlier too, I do not know."
- More frost-free days: "Not sure about water quality."
- Increasing minimum temperatures: "yeah, for the reasons that we just discussed plus, you know its, the pinebark beetle is not able to survive through a winter much more easily than it could before because you had to get like one of the things that killed off the populations was that it got down to 40 below for a week or two or something up in the mountains, and that would just kill the larva and everything and so that kept them down. Not they are much more likely to survive though a winter cycle because of the warming. When you have less tree, and more trees are dying, we all know that, when you have less trees that definitely impacts the water regime throughout the forest. That is a huge problem, and so that would impact quality, and because the trees absorb, or help retain a lot of the soils, and without the trees then you are just gonna have that much more topsoil washing into the streams which would affect water quality, and then obviously, trees are just like with the root systems are kind of like a storage system. It would affect the availability of water in the summer, especially, which is when you need it the most. As you know, the weather in this part of the country is pretty dry in the summer. So you need the snowpack to keep the water available

throughout the year, but the trees are part of that system too, and if the trees are gonna be dying then we are gonna have an impact on water quality and in-stream flow."

In-stream flow (Unprompted mention of climate change)

- "There the use in particular that is a tremendous challenge to in-stream flow is irrigation, and diversion, and to some extent, in-stream flow doesn't necessarily assume that you wont build a dam, but obviously if the river is dammed up it aint flowing anymore. Not that I am against beaver ponds or anything, but once you get into more large scale reservoirs it sort of impacts the whole idea of riverine ecosystems. I guess I would add to that, global warming cause that can obviously reduce the amount of rainfall or snowfall which would then impact the amount of water available for in-stream flow."
- More frost-free days: "Definitely impact in-stream flow, and that is kinda the thing that I have been talking about. You are going to have less water in the stream on an annual basis, I mean if you have got for a variety of reasons if it is warming you are going to have more evaporation, so then there is less water going into the groundwater, and the groundwater feeds back into the streams year round. But if there is less water available because it never made it to the groundwater aquifer, then obviously all that is going to impact the amount of in-stream flow that you have."

Participant #61
Conservation of keystone species (Unprompted mention of climate change)

- "I think just environmental changes over time. I have only lived here 4 years, but I have lived in Wyoming almost my entire life. Growing up in the 80s we had a lot more moisture than we do now. And it seems that there is some natural patterns of change over time with the environment, but it definitely seems that things are drier than they used to be. We are still getting the snow load in the mountains for the most part; we have gotten out of our kind of seven-year drought. It just seems to me that there is some environmental shift in the climate that we are experiencing. So I think that drought could affect these keystone species, so that is the environmental side I guess. What else? Whitebark pine with the mountain pine beetle, of course that has to do with drought too with the trees being stressed. So I guess a lot of it drought, I could see if drought continues or we get back into another strong drought. I could see maybe in certain areas that I have been to maybe, some areas that have high recreational use. One area in particular that I am thinking there is 4-wheeling trails. It is kind of out of control the way that I would consider it. So I would think there would be a lot of sediment load off of some of the waterways from that use. So I think that if there is increased use, there is more and more people moving here and interested in recreating in those areas so that could potentially affect some of these species in the long run."
- Earlier runoff: "I would say same answer."
- More frost-free days: Same

Biodiversity Conservation

- "This card, what I really pulled out of this was this 'ecosystem structure and processes', kind of like the whole shebang, you know? Yeah, you know, I was kind of thinking about species that may be endangered or threat just over time if some of those other factors like drought, and other issues like mountain pine beetle if you completely wipe the mountain pine beetle out or if you just have small pockets of it how is that eventually affect other populations like the grizzly bear, clarks nutcracker, so over time yeah we will see I guess are those ecosystems going to be able to adapt to those changes."

- Earlier runoff: "I am sure it would. I can't say I can think of exactly how. Especially if you look at that time frame that is not really that many years, it doesn't give a whole lot of time for species to adapt. So yeah, it is definitely going to affect them somehow."
- More frost-free days: "That one maybe not so much, and I guess 9 days. I do not know. Probably to a small amount. That to me doesn't seem that significant."
- Rapidly melting glaciers: "Yeah for sure, I would say so. I think it goes back to the same; can certain species adapt in a quick amount of time? Not to say that they need to stay the same because things change over time but yeah where it could threaten the keystone species definitely. And I think it is definitely changing your ecosystem function, the way things operate."
- Increasing minimum temperatures: "I do not think too much, it doesn't seem like too big of an increase to be too worried about. On an ecological scale that is a short time period, so yeah I do not think I would be too worried about that. Probably most ecosystems could adapt."

Participant #62
Water Quality

- "Well, it like we were just talking about here, if we had fires up there it is going to be nothing but mud coming, if whatever water there is. That is what I am kind of afraid of, we will get some terrible fire and then have hellacious rainstorms, flooding and it will be nothing but sediment coming down. And because we do not get the distribution of precipitation through the years so that it soaks in there won't be any groundwater either, or very little. We will use that up in a hurry. So people don't think about really clean water until it is gone, I feel so badly, so sorry for those poor people in Africa where the women and their kids have to walk six, seven, eight miles and carry a jug on their head for their family everyday. I do not see how those people can exist for very long, it is just too bad. The glacier business, I have always been fascinated by the glaciers. Why they are there and then as I begin to learn more about their importance and keeping the streamflow up down here in August/September that is where most of our water is coming from is those glaciers. We have the different Popo Agie Rivers here, and the rivers on the Indian Reservation too; the Little Wind River, there is the North Fork of the Little Wind, and the South Fork of the Little Wind and they come right out of some of those glaciers. Then there is the North Fork of the Popo Agie, and the Middle Fork that runs through town here, and then the Little Popo Agie, and the little one I think there is a lot of the water comes out of that area that I was telling you about in the form of springs, and the underground water that comes out in the form of springs and then runs down Little Popo Agie. We had a real drought here in 1935 and for 18 years I was kind of county historian, and I went through all the old back newspapers and all of the stuff that had been piled up down through the years. One of the accounts that came out was there was an old fella named Bob Hall lived out here in Lyons Valley, and the Little Popo Agie runs right through it. He said, "in 1935 the River dried completely up, enough so that the willows even died." That was the year that there was so little precipitation that it hadn't fed the springs and so on for head of the Little Popo Agie so it just dried up. Sweetwater was practically dry, if it hadn't been for some pretty good springs on the upper Sweetwater it probably would have dried up too. Were I lived up on the North Fork of the Popo Agie out here boy it was so darned low that you could just walk across on the rocks, so that is what I foresee coming down the road for all these little towns in Wyoming that get their water out of mountains, and a lot of it late in the year from the glaciers that are out there for the big snow masses. So for us I think glaciers are critical."

- Earlier runoff: "Sure. You get down to the end of the year if there is no water in the River, and quite a lot of Lander's water is pulled out of the river. It is pulled out through wells right next too it, but you bet it is going to affect things."
- More frost-free days: "It is kind of difficult to know. If there is enough water flows to renew the underground reservoirs, then it would probably not affect it too much. But yeah, it is just like I was telling a young fellow here, I am sure the frost is coming out from underneath because there it is on the surface. Were did it come from? We didn't have no precipitation in the last 24 hours or so. And so, that is amazing, here it is the first of March, and normally it would be the first of April or it would be the middle of April before that happened."
- Rapidly melting glaciers: "Oh sure. Again, when those glaciers are gone I do not know what Lander will do for water. Along with the glaciers being gone from the temperature change, there will also be this thing that they are really predicting everywhere from Kansas to the West Coast in a big drought area."
- Increasing minimum temperatures: "Sure."

Glacier Based Service (Unprompted mention of climate change)

- "One of the predictions that is associated with this climate change is that droughts that we are going to be getting is going to be either feast or famine. It is going to be huge floods, or catastrophic storms of one kind or another just like they are getting today back in the middle West with those tornados."

Participant #63
Water Quality

- "Well I think a lot of activity or use of the land without regulations would really impact the water quality."
- Earlier runoff: "That is really hard to say how that would impact, coming down earlier? I do not really see at this point with a minimum 4 days, no."
- More frost-free days: "I think it will affect water quality in that you may have more algae blooms, you may be warming, the water may be warmer, it just more of a setting for the biology to be active, and that is the main problem that we have seen."
- Rapidly melting glaciers: "Yeah, I think it would. In that you would not have, I think you would have more sediment in the river compared to the past. You would get more sediment, a lot more organics in the river than you naturally would and it could cause water quality problem."
- Increasing minimum temperatures: "Yeah I think it would. You are going to get a lot more runoff, and a lot more sediment, a lot more organics in the river and it could change the water quality."

Native American Cultural and Spiritual Values

- "Any activity or access would be to some of the areas that were traditionally used, they have a specific meaning to certain groups. Either access or use of that area, and destroying it. I wouldn't say completely destroying it, but as long as it is restored would be good in my opinion."
- Earlier runoff: "I think you may have more runoff in the area, and that could be a problem. But that would be natural, I think it would affect it."
- Rapidly melting glaciers: "It may cause some access issue by people that go back and use these areas. So it could be an access issue."
- Increasing minimum temperatures: "That is a hard one to call. It looks like it could be access issue again, anything occurring naturally you couldn't do much about, but it could be an access issue."

Participant #64
Commercial water-based recreation

- "The over commitment of the river, so less water being stored in Boysen to be released to allow that to happen because that is our business. But it is not just our business that I would be concerned about sort of related to this one [native cultural values], that we believe that the water is important for a lot of reasons. The fact that I own a business is part of my lifeblood, but we have to have water in the river period. So those two are sort of tied together if that makes sense, and I think it has been pretty well documented that the Wind River is really over committed and it is primarily all the of the agriculture. Which is, I mean I grew up on a ranch, my dad still ranches but I feel like that is an unfortunate situation because I feel like ag should get some of the water, but it shouldn't get all of the water."
- Earlier runoff: "Well, since we are a tailwater I do not think it would because we depend on water that they store in Boysen. I mean I have mixed feelings on dams like everybody else does that is involved in more conservationist kind of attitudes. I think dams had their place, I think we still need them, we cant just do away with every single one of them, but I am never shedding tears when I see dams removed from rivers. I do not think; I am a big believer in climate change there is no doubt, I do not think there is an question that the science is showing the way. I do think that river run offs tend to happen, but I do not know, I do believe your data that they are probably happening earlier; they also seem sto me to to be happening more erratically, one year you will have this big blow out runoff then you are a in a drought for a few years. It is random, and at least growing up in my recollection is it did not used to be that way. There were sort of things that you could count on, that it just really aren't that way anymore. It seems to me that a lot of rivers in the west have less volume than they used to overall, and I think that is related to the glaciers melting and they are just not, even if you get a big snowpack and you look at the wind rivers and there are photos from the 50s and 60s of these mountaineers that were back there with these gigantic ice fields, and now they are boulder fields. Even if we have a heavy snow year it doesn't replace all that ice, it kicks the snowpack up for the year, but in a warm year it goes rights back down. I do not think an earlier runoff would necessarily affect because that is only because we are a tail water, if we were depending on the free stone stream of the wind river it would absolutely affect it."
- More frost-free days: "Well, I mean I suppose this makes me rethink my answer to the first question. I suppose it could because if there are more frost free days the ground is thawing

earlier it is taking more moisture as we get late spring rains and heavy wet snows and so maybe that moisture gets drawn into the ground rather than runoff so it could affect the amount of water in the reservoir. So it could definitely affect us, so yeah I do think that probably has an impact. I think that would alter my answer to the first question a little bit thinking about the frost free."

- Rapidly melting glaciers: "It sure could, particularly in water low snowpack years because, you know, if we have a low snowpack year and have a couple of those in a row and the water in the reservoir is low and there is not enough water to run our trips late into the season or we don't have the higher flows that allow for improved, I mean you can see our business, the whitewater rafting end of our business definitely gets, sales go up dramatically, and when we have had a couple high water years in a row. The last few years we have had people come back the next day and say we want to do that again, and in low water years that doesn't happen."
- Increasing minimum temperatures: "Absolutely. Because what I think happens is the snow tends to melt and runoff at different rates, and I think there are differences in rates of evaporation, both from the snow and as it is moving downstream, and when it is stored in the reservoir, and I have no doubt that that would have a negative impact on us."

Native American cultural and spiritual values

- "I don't know how well versed in the background in the Wind River/Bighorn water litigation that has gone on for years between the Wind River Reservation and the State of Wyoming, but several of our elders and councilmen, and people that have been involved in that since day one have said the water is important to us for a lot of reasons that have nothing to do with monetary value or compensation, or remuneration, it is just important to us as people."
- Earlier runoff: "It doesn't to me personally, but I know that it does for some of the people that look at the riparian areas and things that have been important to the tribes for hundreds of years because it is going to change species that are available, roots, berries might come and go during different time of the year, all of those things I think certainly an earlier runoff would affect that, and it has, there are years that you hear people complaining because there are certain plants they are looking for either came early and froze, or those big changes change that system and it has a negative impact for sure."
- More frost-free days: "Very similar, very similar, this is certainly tied to the seasonal availability of different resources, and when that is impacted this is definitely impacted."

Participant #65
In-stream flow

- "Positive in-stream flow will keep your fish alive. Not real sure."
- Earlier runoff: "To a certain extent."
- More frost-free days: "I do not think it would probably have too much affect."
- Rapidly melting glaciers: "It will, yeah."
- Increasing minimum temperatures: "A little bit yeah."

Gradual discharge of stored water

- "If you are into farming and ranching that slow discharge is so you can have plenty of water for irrigation."

- Earlier runoff: "Not necessarily, it would fill your reservoirs up a little quicker."
- More frost-free days: "To a certain point yeah."
- Increasing minimum temperatures: "It wouldn't really affect the discharge, because whoever needs the water from the reservoirs will."

Participant #66
Household/municipal water

- "Basically supply and quality are the concerns that I would have with that."
- Earlier runoff: "Sure I think late season supply has always been the limited factor in terms of water availability."
- More frost-free days: "If it is tied back to one, I guess it would in terms if it warms up earlier the runoff comes earlier."
- Rapidly melting glaciers: "A little less sure on that one."
- Increasing minimum temperatures: "I think it would."

Water Quality

- "I guess most concerns are negative, you know. Again if we have reduced water supplies, what happens to the quality as that reduced quantity goes on and then the other possibility is whatever development occurs and what that might do to quality."
- Earlier runoff: "Also too, as flows decrease I think quality can also decrease."
- More frost-free days: "Same."
- Rapidly melting glaciers: "I guess I am not sure that it affects that one either."
- Increasing minimum temperatures: "I think it would."

Participant #67
Lake, reservoir and river-based hunting

- "Well, positively I think Wyoming is a pretty conservative state, but allowing for natural resources to stay the way they are in some of these areas like the Wind rivers allows for more hunting and fishing, and water to be able to flow down into some of the major reservoirs, which I like reservoir fishing. The big game hunting is something that is protected in Wyoming and is kind of a heritage that is going to continue, and hopefully will continue. It will be nice to keep a lot of the oil and gas development out of some of those areas to be able to have Wyoming and the citizens of Wyoming to be able to enjoy that type of recreation for years to come."
- Earlier runoff: "No I do not think it will affect it that much because the reservoirs are still going to catch your runoff."
- More frost-free days: "No."
- Rapidly melting glaciers: "No."
- Increasing minimum temperatures: "No."

Lake/reservoir fishing

- "Well in the future when we have drought periods it does affect the amount of water that runs down into some of those major reservoirs to be able to enjoy that type of fishing and recreational activities."
- Earlier runoff: "No I do not think it will affect it."
- More frost-free days: "No."

- Rapidly melting glaciers: “No.”
- Increasing minimum temperatures: “No.”

Participant #68
Biodiversity Conservation

- “I see the biodiversity conservation as sort of the foundation of the entire ecosystem that is affected by all of these other values or uses. So in a nutshell, I do not know how detailed of an answer that you want, but in terms of the biological and physical world starting at the bottom or the foundation is generally where you want to have the most integrity and that applies to a home or anything else. So if we take care of these things then we make sure that these are ok then we move on to the next use. I look at the other uses that are part of this chart, and I see some of those uses could certainly impact this particular value.”
- Earlier runoff: “It would affect. I wouldn’t be so presumptuous as to say how it is going to affect. There is no question in my mind that it would negatively affect many species that are very specific in their adaptations to that timing and everything from stream flow velocity to turbidity of the water, to water temperature. All of these things certain impact and it stresses on some aquatics, and may actually benefit others you just don’t really know at this point, unless you do a specific study on each one. But definitely that would impact my two top values.”
- More frost-free days: “Actually I do. Not as much in terms of aquatic biodiversity, but I do see the, for example, the mountain pine beetle epidemic that we are seeing. Certainly the warming winters, the earlier onset of spring, yeah, there is definitely an impact. To a little bit on the warming winters, and the shift in the periods where the temperatures are warming up, things like water retention of the forest is changing considerably. British Columbia has experienced along certain streams a flood cycle that was typically a 20 year cycle where the stream would actually overflow their banks, now it is like every 3 to 4 years. That has become a very costly issue and controversial issue, because several studies are showing that the increase is following the average temperature increases as well as the forest service response to mountain pine beetle which is again connected to rising temperatures. The forests aren’t able to retain all this water, and as opposed to every 20 years having a big flood there are not enough trees there to uptake this water, and therefore homes are being flooded along the streams, so it is affecting both biology and sociology of the area.”
- Rapidly melting glaciers: “Definitely, when you have this increased melting that pretty much necessarily translates into increased stream flows or at least your maximum peak flows, and this alters what has been the normal behavior of the streams, and changes in water volume and flow velocity and all this sort of thing is going to change the water chemistry. So your aquatics are either going to have to quickly adapt to a changing PH of the water which is a factor that is extremely important to all living organisms, most organisms have a very narrow range that they are adapted to in terms of the PH of water they are in, and if that changes too much they may not be able to adapt quickly enough to survive this increase in glacial melt.”
- Increasing minimum temperatures: “Yeah, I am not sure, or I am not as clear on how that minimum changes, and the reason that I say that for example, if the minimum temperature has raised 2.6 degrees F, well if that doesn’t do, if that is not taking, unless that is crossing the threshold like 32 degrees F you are still gonna have ice. So how significant that value is

I am not as clear on. There is no doubt that a warmer temperature, whether it is below freezing or above freezing increases evaporation rates and that sort of thing."

Nutrient cycling and sediment transport

- "Certain uses, and I do not know specifics, basically in management decisions whether it involves logging, grazing, mining, and the various types of land management regimes that various forest services apply to their particular unit. So yea, those management decisions are very important on public land such as the Shoshone."
- More frost-free days: "I do not know how significant that impact would be at this stage. 9 more frost free days certainly lengthens one end or the other, or both of the growing season and when you have a longer growing season you are probably going to have more active exchange between oxygen and co2, now how that impacts the water itself in a river or a body of water I do not know how clearly that is understood, I know that I do not know enough about that particular to say one way or another."

Participant #69

Gradual discharge of stored water

- "We have done several studies around our agency that show that the glaciers are receding, and also our use of the water and the understanding of the way that water systems work that provides a lot of late season flow. So a lot of those rivers and streams wouldn't be active in late July or August at all if those glaciers weren't there. So the fact that the loss of these glaciers will result in essentially the loss of those streams for a non-insignificant part of the year. Then that has a ripple effect, it affects your ability to use that water for irrigation, it affects your ability to use that water for municipal, it affects your ability to use it all the way down the line. Well there may be nothing that we can do about that, I foresee that as being a loss of storage for the system that has the potential to affect most everything else below."
- Earlier runoff: "Yeah, as I understand it. The earlier runoff means that you are having a warming spring, which means that you are getting less snow and more rain which means that everything is going to start coming out faster include those glaciers that provide that late season flow, they are going to start coming out faster as well. So that means ultimately it is going to be getting progressively faster, the loss of the glaciers and the loss of the late season flow, which then in turns affects if you do not have enough water, the water you do have is not going to have as good of a quality because it is going to be used so many times over, you know, the pollution levels concentrations are going to get more concentrated and all that kind of stuff."

Glacier based services

- "pretty much the same answer."
- More frost-free days: "yeah to the extent that temperatures are warming that means the same as before, those glaciers are going to come out sooner which means they are going to be gone faster, I suppose."
- "Same answer."

Participant #70
Household/municipal

- "Well I guess, I don't know, I felt it was the most important because water for human use is the most important. Factors that would be affecting it would be the water availability and the quality of the water mostly. I guess you could refer to the glacier studies, if you are losing water supply then there is not water available for people to use."
- Earlier runoff: "Well, only in being able to, you are losing storage, if you lose storage in your glaciers and are not able to store water in other ways, the water is essentially going to be gone, you are not going to have late season flows, so there is just not going to be as much water available, it may be the same amount of water but it may not be available over the same period of time."
- More frost-free days: "Well, I think it could because, I do not know about the municipal water."

Water Quality

- "Water quality depends on how water is being used throughout the basin depends on where you are looking at water quality, but water quality is the most important feature in the basin because all of your other uses actually depend on how good the water quality is. How it could be affected it all depends on management of either the forest with what you are looking at, or any land management activities that are going on, or even industrial development, or to some extent the development of cities and towns they can pollute water through storm water runoff, or all sorts of things. All of the uses essentially depend on the quality of water and maintaining the quality of water."
- More frost-free days: "But the water quality might not be as good in the late season if you have less flow, because a lot of times the water quality is flow dependent because of the concentrations. And it is just a matter of whether you have water available for that use later in the year. It increases your growing season, although if you do not have water late season, you may not really be able to really change crops or adjust to anything like that for water use. And water may be warmer."
- Increasing minimum temperatures: "Right now, all or most of our basins are dependant on snowpack for their summertime water, and more on base flows from groundwater in the winter. So if you do not have as cold of temperatures and you do not have the snow accumulation and it runs off quicker, you are going to be short of water late in the year. Early you may have a lot, but without some sort of storage mechanism you wont have as much water available later."

Participant #71
Education, management and science

- "Access would be one, a big one. A decrease in [bio]diversity would change how much I guess you could do out there."
- Earlier runoff: "Absolutely."
- More frost-free days: "Yes."
- Rapidly melting glaciers: "Definitely the education if that is what you are interested in."
- Increasing minimum temperatures: "Yes, absolutely. Again the decrease in biodiversity would be a huge impact. It would change runoff times, yeah it is all related."

Preserving lifestyles, landscapes, and livelihoods

- "Public perception would be a huge thing if people do not understand agriculture and the culture that that brings, the lifestyle that that brings, how it influences landscapes. So public perception is probably the biggest thing, and that leads to a whole suite of other things. Different groups, if you see things different you might litigate, or you might disagree with the ag kind of lifestyle. So that would be the biggest thing. Other things would be, of course, a lack of water, which it kind of snowballs from there."
- Earlier runoff: "Absolutely, changes your growing season significantly."
- More frost-free days: "Yes."
- Rapidly melting glaciers: "I do not know about livelihoods, lifestyles and landscapes. I would think eventually it would because it would impact irrigation levels, but I do not know how much. I am unknown on that one."
- Increasing minimum temperatures: "yes."

Participant #72
Water for stock

- "Not necessarily water related factors? Obviously a lot of that water is used for stock up on the forest, so the ability to maintain lifestyle grazing permits on the forest would be one of the most critical ones to be able to make that use. In lower areas, it would have to do with making sure that we maintain flows that reach down to those lower reaches of the drainages."
- Earlier runoff: "probably for stock not as much, although it could. As long as there is some runoff because you do not need huge amounts for stock water, so you do not need to take advantage of those peak flows necessarily."
- More frost-free days: "Potentially could be beneficial for stock by allowing a longer period of use when the waters wouldn't be frozen."
- Rapidly melting glaciers: "In the short term I do not think it does. In the long term if that is a trend that continues, which I think is a debatable issue, it certainly could have an impact on the quantity of water that is available, particularly late in the season."
- Increasing minimum temperatures: "I would not see a significant affect on those two benefits."

Household/municipal use

- "I think of that use being made more lower in the drainages not so much up on the forest, although there might be a little bit up there. Just making sure we have adequate water that reaches those uses, as well as quality of water, maintaining healthy streams. So that the water even though it may need to be treated, that it is treatable."
- Earlier runoff: "It might increase the need for storage to meet municipal water needs later in the season."
- More frost-free days: "I do not see it significantly affecting municipal."

Participant #73
Biodiversity conservation

- "Well, I think there is a lot of, since national forests are multiuse agencies or entities, I think there is a lot of pressure to maximize that concept of multiple use. And, I think maximizing that does have an ultimate negative affect more than likely on the biodiversity of national forests. There is, in a lot of areas, on national forests there is too much going on in certain locations, and I think that is the biggest threat that I can see."

- Earlier runoff: "Potentially, I do not know for sure. I suppose if runoff is occurring earlier, which means that it ends earlier as well, then it could definitely affect biodiversity of aquatic and riparian areas."
- More frost-free days: "Potentially, again it hard to know, I mean it is kind of a long term cumulative sort of effect that would probably be only detectable."
- Rapidly melting glaciers: "Yes."
- Increasing minimum temperatures: "In the long term, potentially."

Water Quality

- "Just being in this particular profession, I have been exposed to and educated about how different activities and different projects affect not only water quality, but water volumes and frequencies and availability and it is a similar reason I think, too much going on that is toward development, or overuse can definitely affect water quality, and it not only affects water quality within the forest and upper watershed but also ultimately affects water quality lower in the watershed. So I see, you know, obviously things like over grazing can affect it. It all basically comes down to not managing things properly and having too much going on, it is not that I am really excluding any given use specifically, but I think there is just, many things could be managed better to benefit those two."
- Earlier runoff: "Potentially, but again I am not sure."
- More frost-free days: "I do not know."
- Rapidly melting glaciers: "Yes."
- Increasing minimum temperatures: "Potentially."

Participant #74
Fighting forest fires

- "Here is the deal about the forest fires. The big burn book that was published a couple years ago talked about the extraordinary fire that was in the Idaho panhandle, western Montana, and eastern Washington was horrific and the conditions for that in my opinion would be ripe in the few years as the forests dies because of the bark beetle infestation, and the forest service has been, in my opinion, completely inept in terms of managing the forest. This is the 21st century and we know how to manage forests, and that basically means timbering, and timber harvesting in both wilderness and non-wilderness areas. And while there is tremendous push back about motorized activity, by way of trucks and equipment to manage your forests, the reality is what is the greater good? Well, the greater good is to have a forest that is healthy and forest management practices can create a healthy sustainable forest, long term as opposed to relying on a huge fire, and then it is naturally occurring. So why do I say that? Well, it is sort of the social-economic framework, in 1910 you did not have all of these communities abutting the national forest. You did not have people with homes up on the hillsides in the forest areas with the forest view, now you do. So what is the value of your cabin up on the Shoshone Forest, and I know if it is on the forest it is leased land, but nevertheless the values diminish if there is an outrageous forest fire. In my opinion, not just Wyoming, but Colorado has the same challenge, and Montana is beginning to have the bark beetle infestation, and I have talked with the governor of Montana about this rather extensively, as also our governor here in Wyoming. Instead of having a 50 mile long headwall of fire like we had in the Yellowstone fires in 1988, we are looking at the possibility of 100-150 mile in length headwall that will burn everything in sight and also the ambers will be flying. That is based upon a dry forest condition, a drought condition like we have had in the past in these other states, Colorado has it right now, and a high wind situation which happened in the big burn which will carry the embers 20, 30, 40 miles, so that is why I say it is devastating, and if the forest is completely obliterated or almost completely obliterated, then the ability to hold the soils and the nutrients is diminished and then you start having problems with water quality downstream. So it is an ecological problem, it is an economic problem, and then it also becomes a social problem in the sense that the Shoshone forest is the nations first national forest, it was called a forest preserve then. So, and it is also on the North Fork highway going to Cody, to the park, that is the east entrance to the Park, to Yellowstone, and then going out of Cody to the northwest is the northwest entrance of Crandall area, is the northeast entrance of Yellowstone. Do you really think that people are going to be enamored by a decimated forest? I just do not think so. The park service has been, shall we say, very creative in sort of depositing in the minds of people that the fires of 1988 were a wonderful thing and look at mother nature by seeds that expand when they hit the ground and how wonderful that is. I do not see that is being that wonderful, but to me the publicity PR campaign by the NPS was lets cover our behinds because we basically acted with incompetence, the forest service, the different forests because it was the Bridger Teton Forests, and the Shoshone Forest, that fire was actually caused by an ignorant camper that did not put out there fire. The one on the Shoshone on the south of Yellowstone was cause by lightning strike. Conditions are extremely dry, the fire started raging there was wind, and you know they were going back and forth across the park. Mammoth was almost lost, Old Faithful was almost lost. It took Wyoming Senator Al Simpson who is in the leadership role to bring in the bells to get out and get after it to deal with these fires. It was like bureaucracies and what have you were frozen, the two agencies [FS and NPS] were not talking, it was crazy. Then you add on to that this compounding effect of what we cannot drive into the forest, of course you can't, there are no roads first of all, and it is a wilderness area so we cannot helicopter in, and all of the reasons that we cannot fight it. My observation is, you know, I think we need to get real with man's relationship to nature, and there has got to be a better, a more reasonable saying, approach, what your mother would tell you around the kitchen table. In Europe they manage their forests more aggressively, they do not have the disease problems that we have. I remember hiking in the Swiss Alps and seeing some timbering, but it was very low scale it was basically by an individual, up there with a horse or whatever, it was not like clear cutting. Now that is in Europe, and I cannot say that their conditions are the same as the US, but I can say this, the bark beetle is a national calamity, and here we go USA, not being proactive to deal with the problem. The only forest that has a half-baked chance of surviving right now is the Black Hills Forest, which has had more timbering of any other National Forest in Wyoming. So it is a healthier forest, there still is a timbering operation over there in Hulett that does pretty well, but they are struggling because of the regulations to get in to do the timber harvest in the first place. So it becomes an insidious problem, and the reality is, you know, I do not see people using less paper goods. So, that is what I am saying, we have created a construct that is ripe for a real calamity, and then everyone is going to be yelling and screaming because those lousy bureaucrats did not know what they were doing. And the bureaucrats, in their defense, are saying well we have got to go through the NEPA process, the planning process, we tried to develop the forest service plan, and then we do one of the timber sale, then it is appealed by an environmental group, then that drags on for another 5 or 6 years, and then it repeats itself, and everyone is still using paper. And you also are talking about real jobs for people, and now with the fragility of the forest, you have people who have their cabins, you have people who hike in the forest. The forest service, all they are doing is cutting trees around roads and some of the campgrounds and that is it. What about the trails, some innocent family is gonna be hiking along and a tree is going to fall on them. So, if I was a benevolent king, I would be looking at our correction facilities in this country, and any able bodied person would be tethered in a way which we could keep track of them and train them how to cut down trees and let them go out there and let them cut down trees. It would be a low capital intensive kind of thing, it would be just human labor. But that is what I would be doing. It sounds like I am a crazy conservative, it is not that, it is just being practical. I was around here in 1988, I am the guy that wrote the first news release: "Agencies, get on it, this is terrible." We almost a national treasure in the Old Faithful Lodge, that construction would never be replicated because it was such a beautiful piece of art, and to replace it today would be too expensive. So, and we almost just lost Pahaska Tepee which was Buffalo Bill's original hunting lodge. These historic guest ranches on the Northfork, a number of them were at risk."

- Earlier runoff: "To a certain extent, yeah but I think the forest fires is more related to the bark beetle."

Glacier-based services

- "I think the glacier issue, I look at that as more of a global warming issue. So it is directly related to the health of the Shoshone Forest and the water supply. Certainly if the glaciers are melting there is going to be less water runoff as well, I mean if the glaciers are melted completely, that water storage capacity is lost forever. Secondly, glaciers when the weather is right they replenish themselves, so they drain a bit and then they replenish. I suspect that they are not replenishing the way they used to. I know that there have been periods of global warming in history, Greenland is called Greenland because back in the 700 and 800s there was farming in Greenland. That was obviously, that warming was not attributing to human kind. Current global warming issue is partially related to human activity and probably partially related to normal planetary conditions. Is there anything to be done about the glaciers, probably not and that is just terrible."

Participant #75

River Recreation (Unprompted mention of climate change)

- "The big thing for river recreation, especially in terms of floating, is always flow. The big things that I think we will be facing in the future will be the fight between demand for the water as things expand, potentially as the inflows decrease up through the Basin at large, you know, versus the agricultural uses, the sort of non-traditional uses. I think one of the real interesting threats to that area is it lags very far behind in river recreation compared to Montana and Colorado. There is a book called the whitewater bible of the Southern Rockies, two of their top five runs are in Wyoming. One is the Bull Lake Creek on the Wind and the other is the Clarks Fork, and maybe last year was an odd year because they all ran so long, but if 20 people run each one of those a year I would be astonished. So you have that level, and both those rivers, the wind is kind of a weird deal because it is closed to the public access, more or less. The Shoshone is open all year long, and you do not have people who utilize it. So I think there is a real disconnect between I think what is potentially there, and the few users that are there versus the agricultural mindset that a lot of people have grown up with there. I think, maybe, as time goes on if there are decreasing inflows because of climate change or whatever, that will put a lot of stress on that system."

- Earlier runoff: "Yeah, absolutely. You know, it pushes things to earlier, so it is colder. An earlier runoff would, and then you have a longer extended warm part of the season where it is lower. So the more enjoyable climate atmosphere would not be there."
- More frost-free days: "Yeah, it is less direct and less obvious. Less frost indicates a lot of things in terms of runoff, and transportation of some surface ground water. It also indicates warmer soil temperatures which means less inflow to the river. It can impact in both those ways."
- Rapidly melting glaciers: "I mean in the short term no, in the long term I think absolutely it does. Particularly in the low water years, it is basically just a water bank is what glaciers end up being and help contribute during those years."
- Increasing minimum temperatures: "That is really interesting. Yeah the lower winter temperature means obviously less kept snow, less glacier recharge, it also can indicate, I would think maybe a drying out of the forest, and also the less cold temperatures impacts the bark beetle, and tends to, you are seeing that in Southern Wyoming, and so that in turn if you end of having this devastating loss of timber, that impacts runoff, particularly with fishing because you tend to get a higher sediment load if there is a big forest fire then you get an ash load which is devastating, it could be argued that it might be good for whitewater if you are just looking at whitewater, warmer water would make it more, I guess this would go to all of them, it might make it more enjoyable for some. You could see crazy high spikes in things, and that is looking at the short term, but in the long term less water is not a good thing."

River-based fishing

- "The fishing is a little different in that you need a more, you see a lot more people doing fishing typically, but it is not always in the most sustainable path, there is not a lot of catch and release areas over there, it is a lot of harvesting. But similar problems, they have a lot of problems when the water gets low it gets really warm. They also end up having a lot of trouble with fish entrainment in canals and systems there, and considering that is a native habitat of the cutthroat, you know, and it is funny because trout unlimited for example is trying to work to do a lot of river restoration on unlocking, trying to change the mindset, especially because the irrigators are so, they do not anyone touching their water, I am sure you have heard the expression "water is for fighting, whiskey is for drinking in Wyoming" and it is like that. When you tell them that you are trying to expand the native range for the cutthroat, they don't necessarily, I don't want to say comprehend because that sounds demeaning, but it is not something that they really care about I guess. So, again you are going to have that conflict as I think more and more people are getting interested in that, there is more and more pressure on it, because the fishing has gone up. I think similar problems of one maintaining inflows, two maybe doing some river restoration or enhancement, which in that area people just don't want to spend the money, you know taxes for doing something like that. Any then you know, the intersection between recreation and private property rights, and water rights, especially with Wyoming generally in that area in particular is behind a lot of places like Colorado and Montana, that the laws have not been pushed as hard and there is a lot more grey area. Yeah, so you have access and maintaining the fisheries. Just inherently with the oil and gas, and with agriculture both of things are hard on fisheries in general. I think it is going to be interesting to see how that are going to manage that tight rope of managing the change in the use or the maybe allowing for more fishing, will that be part of planning. I do not know how much if any interest anyone has in that."

- Earlier runoff: "Similar, obviously warmer water which would be the end result of earlier runoff could lead to lower inflows, lower sustained flows of the water which would in turn lead to, especially the sort of fish, the cutthroat in particular are very sensitive to warm water. So, warm water is just devastating to fisheries, and it can really cut down the quality of the fisheries."
- Rapidly melting glaciers: "Yeah, same things. You know, warmer temperatures, less sustained inflows, lower sustained volumes of the rivers."

Participant #76
Household/municipal water (Unprompted mention of climate change)

- "I think if climate change happens the way it is predicted to there is going to be a lot less water available for use, and managing that water resource is pretty important. Water I think is probably the most important thing that is undervalued, we don't really think how much we really need it. So that is why I put it up at the top."
- Earlier runoff: "Yeah, both of them. The water supply which would come from Buffalo Bill Reservoir for a large portion, or wherever, if the peak flow continues to happen earlier and earlier there is a possibility that the late summer season water flow not being as high and a water shortage and those types of issues. So having the ability to capture water, there is going to be more rain happening if it warms up like that especially in Spring and summer and maybe in fall, so having the ability to capture that water might be important to avoid those water shortages."
- More frost-free days: "It is a little bit related to the first one, but I mean that could be good because you would have a longer growing season for some agriculture, but the water issue comes into play there if you have less water in the late summer. So I guess I would say that the longer growing season is going to be a benefit."
- Rapidly melting glaciers: "Actually it is going to increase the water supply just for that small area, and downstream for a while and I think the glaciers are projected to be gone mid century. It is going to be enhancing the water supply for a while, and once they are gone it is just going to be on a snowmelt driven hydrology. Benefit and then…not."
- Increasing minimum temperatures: "Yeah, and I think the water is the major one that it impacts. If that temperature increase keeps going the snowpacks are going to be less and it will be less of a snow driven hydrology up there. Which means that the hydrograph goes for the water year, here is winter we have basically nothing coming off and then it melts in the spring or maybe even earlier and then it drops off, and then you go around on another cycle. If you are more rain driven you might see, you might be lower and then you have that peak earlier, it will be a lot flashier, maybe you will have that flooding, things could be a lot different, a huge hydrological change, and then there is the affects on all of the wildlife, and the the forests up there in terms of how they are going to handle that change in the water and

how it is going to affect their food supply and that kind of stuff. Then what is downstream of all that having to deal with a big change, and when that timing of their water gets there, and how much it might be, and great quantities during a flood. Just really a lot less predictable."

Preserving livelihoods, lifestyles, and landscapes (Unprompted mention of climate change)

- "That strikes me as kind of the whole picture, the economics, the landscapes the ecologic, and trying to preserve all of those at once. You know, making choices in how the resources are managed so that all of them stay healthy is a big one. I think up on the Shoshone the models are predicting now and in the future they will probably see a little bit of a precipitation increase, but the temperatures could go up anywhere from 1 degrees C to 6, or 2 to 10. It is just a big range of possibilities of what could happen, and if the temperatures go up that much there is going to be less water, there is going to be more pressure on the landscape for grazing probably, for wildlife, it is going to be a tougher time for a lot of species, and the agriculture activities. So keeping things healthy and resilient as much as possible I think is an adaptive step that can be taken to help the whole picture; everything up there, economically and ecologically handle and adjust to these possible changes that might happen."
- Earlier runoff: "That is certainly going to have a big impact on the agricultural community when water dries up in the summer, and also for the ecosystems up there."

Participant #77
Water quality

- "People can use water quality as a regulatory agency without people, federal guidelines. State authorities all those laws and everything, the number one factor is the quality of water and that is what, that is who tells you, that who tells you stuff. If you listen, you can hear and listen, people can't; they need some state office, then they send you to a federal code of regulations, we do not need that stuff. Quality is who tells you, this is how you should be living. It is easy, the simplest way, it doesn't require technology, all the big stuff; If you don't got water, you don't got nothing, and if that is not a factor I do not know what else is. It should be the same way, cause when my grandfather build his house, he build above the floodplain without the federal authorities telling him this is the 500 year floodplain. He knew how to live, they could hear, and they were aware. Today these people, with all the high technology they are not, my grandfather knew the weather because he lived outside, and if you do not do that, it is simple, you can hear, but people do not want to listen. They want to do their own little deals all over the place. I am not too sure if I answered you there. If you do not have no quality in your water, you can go through all sorts of things but you are gonna dry up."
- Earlier runoff: "In my views there is no line between fall, and winter, and summer. There is no day, so you are not listening again, you are going by maybe the calendar or the clock. So that is not connected, you are disconnected when you got a clock, that is why I don't got a watch and I don't got a clock in here. There is no boundary, there is no line between seasons. Crows, people tells us four, but the names, there is three and they all in between there. Some days, evenings, nights, in between there it is the same thing so you have to when you say climate, you are not listening again. It has been telling us way back, but you still operate same time zone that you are in, that is the problem."

- "It goes back to the earlier runoff, frost. When, when is it frost free. You want a frost free early in the fall, early in the winter, or late in the fall you want frost. That is different then frost in the spring, so doesn't really, the number of times of frost in the year, we are still going to get frost and it is going to affect us pretty heavy. I am kind of thinking, the ground never really iced up this fall, so that doesn't mean that it is not going to ice up even though somewhere, in Switzerland I think it was, about a month ago that is quite a bit of snow in that area, but I know that is totally different. You look for winter kind of country, they had a lot of snow, so that doesn't mean that we are not going to get no, you know it is just going to move around. If we get frost late, that is the difference in everything. I told you on the way, in no, it didn't always die when frost came late. They just have to change, some of those boys want to get out there, but if they do then the plant will come out and the frost will kill them. So you just got to be patient and go out there at the right time, they still do that with sugar beets. The boys with the sugar beets get anxious and then the sugar beet comes out and you don't get the moisture, so they die. So they got to go back out there, they didn't go back out there they still made it. Some of those guys they, I know I live buy, I go buy these fields, they thought they re-drill, they went out there and they replant it, and they didn't get to this one because they got mud or something, and those ones they didn't bother with, they came up again. They killed it, but they didn't die, something happened and later on those leaves were just the same, both sides even though those people thought they helped their field and they ended up being the same thing. I didn't look at the beet after it came up, maybe they were different."

Native American cultural and spiritual values

- "Well, kind of that is kind of like your ground, your upbringing. Where they always tell you an ethic, you have to have a work ethic, so it is the same thing, that is where our people came from. Our way governing, our way of teaching, our love for each other came from that River corridor. Society is based from where the water meet the bank, where the water and the ground became right there, it is where all the wood came and stayed together, so they took that and made it our whole tribe, and whole society, our life, that is where it came from, and it took those pieces. So, if we don't lose our values and all of that as a people, we are disconnected from where we came from, and a lot of these kids are like that today. They probably never even gone out and seen what me and John seen in the creeks and the valleys, and they haven't been out there, so they haven't had the connection of the air, and the plants, and the bugs, and all that. So that is kind of like losing your culture and your language, and when that goes away I think it is part of our, we don't take our respect for ourselves and our land, we think it is separate. It isn't, it is all the same as a person and I always tell John that water is our mother, but he doesn't believe me, but he thinks the ground and the dirt is our mother. That is our stories, we come out of the water."

Participant #78
Water quality

- "Negatively is the disregard of what we are doing along our river. There is too much, I guess there is too much livestock feeding along our rivers. Really, there is no real setbacks that allow for the natural filtration systems to protect those streams. To me that means health for us. If we do not have a healthy stream, then it is going to affect our personal health in some manner, so that is why my concern is there."

- Earlier runoff: "We have seen it happen, because the rivers are so low that our intake water was almost in a stagnant pool, and so the runoff, if it peaks early and we do not have that continual flow and our groundwater resources haven't been recharged from snowpack, then the springs are not going to feed that river. Twice in my recent memory we have seen that little Big Horn river nearly dry, and you could walk downstream without getting wet above you ankles, you would have to search for deep places."
- More frost-free days: "Well, you know that is kind of a tough one, they all tie together, if our river is open that river has to go through that cycle of freeze and shut, to me you know it has to, and so that is part of the natural process of the river, and you know that freezing and shut that does something for that river, for the water quality. So when we don't have, if it is not closed up, this winter was that way. It froze briefly there for a couple of months, but there was large stretches of the river that were open. So we do not know what that means for us this summer. Is that kind of an indicator for a dry summer, I guess we will know later this summer. Frost-free days, I guess for some people they are going to like it. Depending on what you do, if you are into agriculture, but again that changes that whole cycle of the earth. You got to have that, some plants depend on that cycle, and bugs and insects do to they have to have that cycle. One of the things that we do not know yet, and this summer, new years day that should be the coldest and everything should be shut down but I had a plant come out of the ground that high, and it was green and fresh, my thoughts when I was looking that was the trees, choke cherries and plums because if they start that same budding process and we have one of them surprise late frost, and we refreeze that wood it is going to affect that production. Plums that happens almost everything year and I am beginning to wonder that them guys must be not native to our area because we very seldom get plums anymore because there seems like there is a late frost, it used to be that the plants bloomed in late April or early May, then the middle of May we will get a frost and no plums then. They are the best too, wild plums, but shoot. In some places they grow but we have been missing it here a long time. It is mild too early, and then it starts, and then you get that late frost. Just trying to delay them blossoms."
- Rapidly melting glaciers: "The glaciers do affect us if they are the headwaters of the Bighorn, and so at some point the less water we have in storage back here. Maybe not so much anymore, before the storage was there I am sure that the had the affect on the rivers.

Household/municipal water

- "It's the same thing. They tie right together, is how we treat our river. We are probably the only community besides Hardin that, on the reservation, uses surface water for its municipal water. Wyola, Lodgegrass, Pryor, Fort Smith, they all use groundwater. And so, we use surface water, so the quality of the rivers is critical to our drinking water. This past summer when we had that flood, there was near panic level because of what was in the river already, and then the Lodgegrass Lagoon got washed out and so that was headed downstream fast too. So, for three days our water plant was shut down, and so the planning part of it is just as critical as that water quality. How do you plan so you are not creating a dilemma at some future point?"

Participant #79
Education, management and science

- "You know I do not know how to answer that, I am sorry. I really do not, to me education is most important because you are training the next generation in what your values are with that resource. And you are showing them what is important, and if you are not doing that then nobody knows. The reason that I went into forestry is because early education that I had, you know, and so that is why I think it is important. I do not know what would affect it negatively though."
- Earlier runoff: "Well, you know, I think that whatever is happening with the waterways you can use that as an opportunity for education."
- More frost-free days: "It does, because basically every species has some kind of marker that it is looking for, and I am thinking about trees specifically because I am a forester, but they need a certain number of frost free days before they can experience bud break and start to burst forth through the new season, and having new growth and everything. If that is happening earlier, you know, it is impacting the trees and their health. I know that, and it confuses them, especially if we have frost free days and they start to bud out and then you get another frost or something like that, you know then aesthetically that is negative because you are not getting the full leaf out effect."
- Rapidly melting glaciers: "Then you also can't study them, and learn from them. I am from Michigan where the entire state was formed by glaciation. It is something that people study, it is like why do we have these rocks here because it was literally dragged down by glaciers. If the glaciers weren't there you would probably not be talking about them anymore."
- Increasing minimum temperatures: "Well, yeah for the same reason with the trees not budding at their normal times, not going into dormancy at their normal times. You know that will affect, and obviously the trees doing that affects all the wildlife as well because they are not out, you cant do any wildlife viewing if the wildlife doesn't have anything to eat. Or if they come out early and the trees are not ready for them then they are all hungry and they all die off. It also ties in with education, because again if it is not there or not there predictably."

Inspirational and aesthetic values

- "Yeah, aesthetic values can be impacted obviously by industry or by just kind of any sort of eyesore. Improper management, people not using best management practices and kind of degrading stream sides and that sort of thing, which I think is usually illegal, or dumping in the river which does happen on the reservation. I mean there are some really dirty waterways that, I mean you get up into the high mountains there is nothing more beautiful and pure, I mean I drank from the streams up in the Bighorns all summer and I am still alive, and I didn't boil the water or anything, but would I do that with the Little Bighorn across the street? No way. Everybody that lives here in crow, there stuff is kind of dumping into it, sewage is kind of spilling into it, sewage lagoon and things like that."
- Earlier runoff: "Well, an earlier runoff basically creates flooding. Is that what it would be doing? Yeah we had a huge problem with that last spring, and that impacts everything. You cannot get anywhere because both of the intensity of the runoff, like how fast it was happening, and the fact that it was happening earlier than it had historically."
- Rapidly melting glaciers: "I am not sure on that one, I mean I would assume that you could have the same problem with an earlier runoff or a heavier rainy season you could have

flooding, and again the glaciers themselves are aesthetically pleasing. My understanding of a glacier it is anything that doesn't melt throughout the year basically, if suddenly they do melt then they are not there anymore, I mean."

Participant #80

Commercial water-based recreation

- "Mostly just because of the fact that anything that has to do with commercial based stuff, is going to have to, money talks in a lot of cases. So if anything comes up with any kind of, if it is hydroelectric power, anything with commercial fishing, or irrigation those are going to prohibit a lot of things that I enjoy doing for rafting, kayaking, fishing, and that kind of thing. It is going to be switching, with the dams and the salmon migration kind of deal, it is going to flip and flop back and forth. So I think commercial water-based stuff is a big, water is becoming more and more of an issue, and I think in the future I think it will become more of one too. I think the commercial side of things is going to try to control a lot of that."
- Earlier runoff: "I think yes and no in some cases. Just for the fact that they can trap a lot of the runoff, it doesn't matter what time of year it comes it can be put into reservoirs and stuff like that, holding tanks, ponds and stuff like that, I think for the most part it shouldn't, just as long as we are getting that same annual amount of precipitation I do not think it matters when or where it comes from."
- More frost-free days: "Not for me."
- Rapidly melting glaciers: "Yeah it does, it will give you some more runoff for sure. I think that you know, for the stuff, livelihoods, lifestyles I am not sure that will fall into recreation, but it could. Some people like to go up there and do a lot of the ice-climbing and stuff like that, so that could be one, guides might go up there livelihoods, or lifestyles people like to go up there and enjoy that kind of thing. As far as the runoff, if the glaciers are melting that is going to add some volume on to whatever the annual precipitation the area already has."

Preserving livelihoods, lifestyles, and landscapes

- "There again, I grew up at the river quite a bit with stuff like that, and it is part of my lifestyle and some peoples livelihoods, in some cases for ranching, and I grew up in the desert, and water is huge. It kind of wraps back into the commercial side of things when they are just going to do the trickle affect; find the most important and then go down from there. In most cases I would say recreation takes the bottom hand a lot of times when it comes to the economic side of things."
- Earlier runoff: "For that one for sure because depending on when you are getting your, as long as it can hold the water for a certain amount of time that is fine, but I mean if you are working ranches or farming and stuff like that crops come at a certain time of year and some commercial based stuff as well. So I mean during the spring flows all the hydroelectric dams are running full time, and stuff like that so, I would say, there again, yes and no it kind of depends on the topic."
- More frost-free days: "Maybe just for, actually no I think it would be ok."
- Increasing minimum temperatures: "Yeah, like I said with Rapidly melting glaciers you are talking about the whole glaciation deal, and if the temperature is going up it is going to melting them more rapidly, and it will be making some impacts, kind of if you get those

heavy runoffs, on the snowpack and glaciation it is going to make things more dicey like this last spring with the floods."

Participant #81
Hydropower

- "Getting in the way of it? Right now the Crow Nation received a water settlement, and then the water settlement we have the right to develop a hydroplant right here at the Afterbay. And so, there are so many kilowatts of power that can generate and the Crow Tribe can do whatever they wish with that resource. Whether to provide local subsidized maybe, lower the prices, or they can sell if they can get on a grid. One of the things I see as REA Bighorn County Electric, there prices seem to be more, are higher than say Montana power that feeds Hardin. Bighorn electric does not serve Hardin, but all the people that are on the board are from that area from Hardin, and a few non-Indians on the reservation are on the board as well. So I don't, that is primarily the reason that I think we should pursue this because I do not think that it is fair. I think that there are, for whatever reasons the prices are not where they should be, because I used to have a house in Hardin and I have a house on the Reservation and I get a bill for each one and even though I was at the one in Hardin more and less at the one in Wyola the prices were pretty much almost the same. So based on that, I begin to get this feeling that it wasn't fair, and that for whatever reasons good or bad, it is not equal, so that is primary reason I think we need to do this. Also, we have like 20 million in this for hydro in the settlement that is just sitting there waiting to be developed."
- Earlier runoff: "I am not sure. It seems like the water might, and earlier runoff means it will probably go lower sooner, so that could impact it."
- More frost-free days: "I am not sure how. Maybe, I do not know depending on if the guys like working in the cold. Digging and mining, it might have some, but I don't think it really would."
- Rapidly melting glaciers: "Not really."
- Increasing minimum temperatures: "I am not sure."

Oil and natural gas extraction and mining

- "The other thing I seen is that in the development of natural resources we need water. We need water whether it is a project like ministers where you are looking at coda liquids plant, or oil extraction or whatever you need water and so, with the settlement we did get so many acre-feet per year. And so, unless we utilize it is water that we are not going to be using and it going downstream and so, I think we need to capitalize on it and take advantage of it when we can."
- Earlier runoff: "It depends on how many acre feet we got, and how many we got for development, so much per year. If we have senior water right it is fine, but if we don't then that could be a problem."
- Rapidly melting glaciers: "Not really."

Participant #82
Education, management and science

- "Harm coming to them, I do not know too much about that. I would prefer they would leave things alone as it is with the water. Just stay the heck away from it."

- Earlier runoff: "Quite a bit. Last years flood. Like Hardin for instance they have that thing there that is affecting the water, and the fish in there. The air or the smoke that is coming out of there, and then maybe it is Billings too. I do not know the farms there, but I know there is a lot of mercury in the fish."
- Rapidly melting glaciers: "I have read about it and heard about it."
- Increasing minimum temperatures: "Probably, it is not the way it used to be. I know it is not as cold as it used to be, there is just too many changes."

Native American cultural and spiritual values
- "We were taught to respect the water."

Participant #83
Commercial irrigation
- "I think there should be more studies on the spraying of insecticide and herbicide. My brother lives on a portion of our land over in the Bighorn Valley, and they did a test on his well and there is a high concentration of the stuff to help plants grow better, so that he cant even drink that water. So he needs to bring water in. I think that we need to do stricter studies on that, so either dig our wells deeper or do something to monitor the farmers so that they do not over spray their crops."
- More frost-free days: "No."
- Rapidly melting glaciers: "No."
- Increasing minimum temperatures: "No."

Water quality
- "We need clean water for the fish and the wildlife, and for the aquatic bugs and animals, and everything smaller than that. We need to watch the water in the Bighorn to make sure that no pollutants get in there and kill the water animals. I used to work for the EPA and we went up to Fort Smith and their sewage, they are doing some work on their sewage now, their sewage pond, you go over their and look in it and there is no sewage in it. There is breaks in the line and that sewage is leaking to the clay down below it and running into the Bighorn. They say that is why there is so much green vegetation in the Bighorn is because of that, before there wasn't as much. I think that is a really big factor there. Trying to keep the Bighorn Basin clean is to get that sewage lines worked on."
- Earlier runoff: "I can talk about the little Horn, not so much on the Bighorn. On the Little Horn they feed their cows next to the creek, so when there is high runoff a lot of the cow and horse manure goes down the little Horn and then it flows into the Bighorn. Up here there as not as much of that on the Reservation side, as there is on the little Horn. Yeah on the Little Horn it affects it, the runoff affects the quality of water on the Little Horn, but I do not think it is that much on the Bighorn because they do not feed that close to the Bighorn and it is all controlled on there where there is not a lot of flow coming down to flood those areas where they feed cows."
- More frost-free days: "No."
- Rapidly melting glaciers: "No"
- Increasing minimum temperatures: "Yeah I think the warmer water affects the fish and probably the oxygen that is in the water like trout, trout like the colder water, brookies like

the colder water and it could affect them. The warm water helps the aquatic plants and stuff grow, and I think that affects the fish also."

Participant #84
Native American cultural and spiritual values

- "If the Bighorn Recreation Area is developed, yeah it is going to affect our cultural sites in that area. The Lovell, in that area that you are talking about, that transpark road goes right through the heart of our prime hunting grounds [a proposed road]."
- Earlier runoff: "Farmers do not irrigate until about the last part of June, or the first part of July. By then the runoff has already come and gone, so it doesn't really matter. [irrigation]. Not really [cultural and spiritual]"
- More frost-free days: "No."
- Rapidly melting glaciers: "No."
- Increasing minimum temperatures: "Less water means more fires which affects that area I was talking about, yeah, which damages the cultural sites that are in that area."

Natural flood control

- "It hasn't flooded in the Bighorn valley. The negative side is the cottonwood trees, I guess they regenerate by the floods every year. I guess since it doesn't flood every year it is affecting them, they are not growing as the way they should be growing."
- Earlier runoff: "Yeah, like last year they had to open up the flood gates on the Bighorn and that brought up the river to just about flood stage. They do that it affects all the way down to the Gulf Coast."
- More frost-free days: "If there is frost, there is no snow, that means there is less runoff."
- Rapidly melting glaciers: "There is two dams on that river, so the glacier I think, Boysen dam I think, I think that takes up most of the runoff from these glaciers."
- Increasing minimum temperatures: "The hotter it gets the less water there is, for flood control, no."

Participant #85
Water Quality

- "Well the water that we have had and drank for all these years down in Crow until of late has always been somewhat polluted with things that can be detrimental, and we really haven't fixed it, I guess. So, water is not of the quality that we should be having and drinking from, so, the wells are drilled, I mean it is probably just like drinking almost straight out of the Little Bighorn River, you know, from Lodgegrass. So that is what you would have to look at, is it is a subsurface water and the drilling is really shallow, so that is the water that we get. It all boils down to drinking water, and water quality. Animal consumption, crops, irrigation. Crows might not necessarily plant the land and use the crops, but it leased and if the farmers are not having a good crop then it impacts them. "
- Earlier runoff: "Yeah, I think so probably. I just of opinion, but I think an earlier runoff would impact the water quality."
- More frost-free days: "Well, it has to have some affect, but I do not know exactly what it would. Frost free days, you mean it is warm?"
- Increasing minimum temperatures: "Well, I think it can have an impact. Maybe the ice building up, and then it going away. I know it is certainly, we used to have more of an

impact where the ice would jam and then all of the sudden, if there is an oxbow or whatever they call it, that might break across this way, and then that has a lot to do with that, the quality of the water, what is being jammed up behind it. People might go out and use dynamite to blow up the ice dam to make the river flow."

Native American cultural and spiritual values

- "That goes to water quality, and you know, I am sure people mentioned in regards to very important internal, or it has been with the Crow Indians for a long time, the so called "sweat", and it is very important. When you have no place to sweat or dip after that, you do not want to dip in the river so that affects that, you know, the pollution that goes into that river."
- Earlier runoff: "Well, it could, and it perhaps could go both ways. Because the old timers say that when, they viewed the snow that comes and falls, or the snow that melts and runoffs as, they think it suppresses disease, and this year, for example, there seems to be a lot of coughing and sneezing and wheezing and we have not got a whole lot of snow. I think they look at it from that standpoint, the weather was extremely important part of the day to day living and the values, so I think that could have some impact on it."
- More frost-free days: "I think it can."
- Rapidly melting glaciers: "Well, we are pretty much in land and I am sure that has an impact on the type of precipitation that falls on the mountains and the rain and that all coming down, and that is all significant and important, so yeah."

Participant #86
Fighting forest fires

- "Just knowing how much damage it could cost, and just having that access to water and even having the storage to water. Just because you know it could cause a lot more harm. I was just thinking of like damage control, because I can see how much of a problem that it is and just knowing that having that access to water, that is how I see it is most important because it could cause a lot of harm and do a lot of damage. I am not sure because I guess it just kind of depends on where the forest fire is, and I do not know how, like years ago we would see these helicopters and they would come down and they would get water right from the river and they would go and haul it to the fire and release it. It was neat that they just had that access to water, which I didn't really see it is a problem or anything, but a forest fire so grand it would take a lot of water to put that out, and it just seems like things wouldn't move fast enough."
- Earlier runoff: "Well, yeah because it, the land dries out a lot quicker and so, when you have the climate change you see a trend with, you will see a lot more forest fires and you will see a lot more flooding, and the runoff that we are getting is coming up a lot sooner than what we are experiencing. Now we are experiencing those two problems, fires and flooding."
- More frost-free days: "Probably, I would think so."
- Rapidly melting glaciers: "Yeah, I would say so."
- Increasing minimum temperatures: "Maybe."

Natural flood control

- "Poor management or good management, we have had flooding here this past spring, and I am kind of predicting that we might be having more flooding this spring. So, I mean it is just preparing for it and knowing what to do because last it was a little bit chaotic because people didn't know where we are stationed, you know, to get aid. Flood control, it would be nice to, like the dam how much water they can release at a time before it really starts overflowing, yeah so, management could be one thing that could make it or break it."
- Earlier runoff: "Yes."
- More frost-free days: "Probably, I would think so."
- Rapidly melting glaciers: "Yeah."
- Increasing minimum temperatures: "Maybe."

Participant #87
Water Quality

- "Well, having made it one of my top priorities I think water qualities reflects the health and vigor of the forest and of the wilderness area above us. It also, there is just something intrinsic about being able to rely on the quality of the water that we have got coming down out of the Shoshone National Forest. As far as things that affect that quality, I think we have got some, the fact that it is wilderness area for much of the watershed, on the middle Fork of the Popo Agie is a great asset to water quality. It will be interesting to see in terms of what might affect it, you know, we have got some huge mineral, oil and gas development to our south and west, and you always wonder in terms of air quality what might be coming up with the prevailing southwest winds. I think another factor, would be some kind of catastrophic fire, basically would inhibit the ability of the entire system to filter to maintain that kind of quality. Other than that I think we are set pretty well as far as water quality is concerned, and you know, I just think water quality probably is going to affect, in my mind anyway, all of the rest of the factors you asked me to rank in terms of importance. It starts with good water, if you don't have that you don't have anything else."
- Earlier runoff: see other question one
- More frost-free days: "Once again, if things are going to continue to get warmer and I do not know so much more about, about warmer because, to me it is not so much about temperature as it is about not only the amount of precipitation and the distribution of precipitation throughout the year, that is why I think the first question is probably more important in terms of biodiversity and water quality. I mean, if we were to move into a more temperate zone temperature wise as far as the mid Rocky Mountain area is concerned I do not think it is a huge concern, if we receive more summer rains and little less winter snow then that doesn't hurt us. Well we are in the middle, you know, the national weather service right now for this 5-70 period we are above average temperature right now, and it is supposed to last through this week and they are talking about ice jam flooding. Just because there is so much water, you know, water levels are starting to rise a little quicker than we normally, it breaks up the ice and then we get these ice jams which can cause, which backs up water and then when it releases you get this flooding. And that is one of the things that they talked about in 2010 with the flooding that we had down this drainage, there was probably some of that ice jam flooding going on up the drainage."
- Rapidly melting glaciers: "It is tied into precip, I mean there are forests all over the country that have good biodiversity and they do not have glaciers, I mean the Winds are this,

especially on the east slope, it is kind of cool that we have glaciers, but there again, if we are going to lose the precipitation it is a problem, but if precipitation changes from ice or snow to more frequent rain in the summer. I mean, from a historic, there are certainly significant, and I think that the glaciers probably, they do moderate our water flow. Yeah, it affects water quality."

Biodiversity conservation

- "I think, once again, is kind of like healthy body, healthy mind type of think. That biodiversity good, healthy habitats, good healthy diversity of species reflects the quality of the forest, that all fits together with water quality. The two go hand in hand, if you have got that good diversity it is a reflection of water quality, and the good water quality is a reflection of tremendous biodiversity; good healthy forests and ecosystems."
- Earlier runoff: "I think, I am looking through these and I have lived, I have spent the last twenty years on this park, and so, I have some anecdotal, and I also like to look at historic trends, especially in terms of precipitation. The thing that I really see is we have gone from a situation where we had more of a balance between winter snows and the late spring/summer and early fall rains. And as I look back through the research it appears to me that, I do not know that the amount of precipitation has drastically increased or decreased, but the way that it is coming down has definitely changed, and it appears to me that we are getting much more of our precipitation in the form of snow, and we are seeing drier and drier, basically, especially through the summer months we just don't see the rainfall that we do, or even that I saw or even in the early 90s, and you know, I have been in Wyoming for over 40 years now and I think that I could carry that over. You just don't see the summer rains, you don't see the monsoon rains as much through August. And, I just think as a result of that you know, however that works, I have been here through the 90s the 2000s and now we are going into the teens of this decade and I would agree that, well during the drought especially, and that may have skewed some of this because we saw runoff in, especially through this canyon in late May, we were done. And then we were looking at 5 or 6 months with relatively no moisture, and so I think this probably skewed some of that into the 90s, you know, for example last year was kind of an anomaly, had a decent snow year, our temperatures were very moderate, and so we never really had a big runoff and yet it was warm enough to keep the runoff going and you know we went into early July, which is I think, that is the way you would like to see it. I think if this trend of really, of earlier runoff and of drier summers continues, in terms of water quality it is really going to affect it. We really saw a tremendous decline in riparian areas and wetlands during that 5 or 6 year period of really heavy drought."

Participant #88

Non-motorized ice and snow-based recreation

- "Climate change is the big one, because I am a skier. You know I go skate skiing up there, and we are all really worried about the snow not being there, and I helped the high school team with timing and stuff like that for their races. We just see it each year more and more, everybody worries about whether there is enough snow up there, or anywhere."
- Rapidly melting glaciers: "Yeah, for all the reasons that I talked before with less snow, less activities for all those reasons. Plus in Lander, this is the international headquarters of NOLS, and they headquarter here partly because the Winds are pretty darned wild, and you

know my son too a mountaineering class for 30 days and went up to Ganett peak and did the glacier thing. You know, NOLS may just say that if that stuff is gone and changing we are going somewhere else, which would really affect our community."

Recreation/leisure activities done near water

- "Well, climate change for all of the same reason. But also, just the way the forest may manage their land. It is too much commercial development, as well as too many, it seems like the forest does not control people up there at all. They camp everywhere, they do everything and if they do not get that under control it is going to be really bad, it is just going be the yahoos are going to take over and we are not want to go up there sort of thing."
- Earlier runoff: "Especially the recreation near water I think. And another thing that I thought about is the whole beetle kill thing, and all that is going to change the forest tremendously, we keep saying, gee this is all going to be Aspen in 20 years and that sort of thing. So that is just, runoff to me equals warmer climate equals dead trees equals changes and all that sort of thing."

Participant #89
Household/municipal water

- "Our water comes from a huge aquifer under the ground that I am sure if fed by the forest water, and it is just very important that that stays pristine. It is good water, it is wonderful water, it is huge it goes all the way up Horse Creek it goes all the way up the Wind River. And so, that is probably the most important thing for us to have our water clean."
- Earlier runoff: "Not really."
- More frost-free days: "1999? We are not even talking about the 2000s. We do not want to about the next 10 years, we do not want to talk about data that came in the last ten years, we do not want to talk about anything after 2005 because that does not prove. The last 5 years does not hold up to the hockey stick theory, we just want to talk about up to 2005. After 2005, we do not want to discuss anything after 2005."
- Increasing minimum temperatures: "Well, I would have to see it over a sustained period of time. You know, last year everybody was hollering about how bad the winter was. I have been hear 47 years, and when we came here this was normal. This was a normal winter. This winter we have gone back, so who knows. I think climate is that way [all over the chart], and I don't think man can do anything. My analogy is the one with the little fly sitting on hub of the chariot saying, "Oh look what dust I am raising." I think that is how much man affects climate, I think it is affected by natural causes, it comes and goes. I mean, Greenland was a paradise at one time. That was real global warming, and we didn't have any man made hydrocarbons in the air then. Stopping a dieing forest would be a way to do that [mitigate for warming]. Who says that the warming is causing the beetles, it is the old trees that it is letting the beetles in. If it wasn't for the age of the forest they probably wouldn't get a hold of."

Preserving livelihoods, lifestyles, and landscapes

- "Something affecting our water."
- Earlier runoff: "No."

Participant #90

Conservation of keystone species

- "I think the first thing that comes to mind would be there is lots of pressure in Wyoming to develop natural resources, and the first indicators of change over time are keystone species. And on the Shoshone National Forest if development were to take place in places were it is already intact habitat, especially in roadless areas on the Shoshone National Forest, I could see that being the most detrimental to these species like cutthroat trout, and whitebark pine."
- Earlier runoff: "Yeah, changing, an earlier runoff could change a lot of aspects of what species depend on. Whether it is a habitual relationship to finding water during certain time of year, or migration of certain keystone species. All of that could easily be affected by a changing, earlier runoff."
- More frost-free days: "I think it is a similar thing to the first question, that dependency on certain aspects of the resource of water on the Shoshone National Forest."
- Rapidly melting glaciers: "I think over a longer period of time this would for both, it is a little bit less dramatic than some of these other pieces, but I think maybe it relates to conservation of keystone species a little bit more in that, I guess some species that would be dependent on the glacier, not necessarily the glaciers themselves, but the habitat that is created around glaciers, you know pika come to mind, they depend on that cooler climate that is created up in the higher elevations where glaciers are. I could see that being affected."

Water Quality (Unprompted mention of climate change)

- "It would be some of the same, and I think the other main thing that comes to mind is climate change and how that is affecting our landscape. In relation to water quality specifically, over time on the Shoshone National Forest there is been very little development as far as, you know, dams to or hydropower development. So it is a relatively intact ecosystem and with the changes that climate change is bring to this forest there is a direct correlation to water quality that we have currently being affected, especially if there is forest fires that are large scale in the future with beetle kill relating to climate change. Even the factors of places where there is current roads that sedimentation is occurring that can have runoff over time with the climate change, that could affect that."
- Earlier runoff: "Yeah, water quality I guess in the aspect of, I have lumped a lot into water quality, but you know, in relation to how people use the resource too. An earlier runoff is not going to bode well for people that use the early runoff for irrigation and other things downstream."
- More frost-free days: "I think yes to both water quality and conservation of keystone species could be affected."
- Rapidly melting glaciers: "I think it is too a lesser extent, like I said, like over time more."
- Increasing minimum temperatures: "I think for both, the conservation of keystone species and water quality an increase in temperature is going to affect how they can both relate to that in the future for species, and how water quality is maintained and changed over time. With an increase in temperature, from my understanding with water quality, that changes the whole ecosystem that we have as far as having such a great water quality resource on this forest. From everything from sedimentation to the climate change with temperatures increasing water quality is going to decrease because of temperatures. Temperatures increasing in the water, any ecosystem is going to be affected."

Participant #91

Non-motorized ice and snow-based recreation (Unprompted mention of climate change)

- "Climate change is probably the most important. I would say that is probably the most important."
- Earlier runoff: "I think it would, not so much the runoff. I guess it would just be the availability."
- More frost-free days: "Not necessarily, I do not think they would affect those as much."
- "Probably the same thing."
- Increasing minimum temperatures: "Yeah, I do on those."

Participant #92

Education, management, and science

- "Well, when I think of education I always think of sharing what you know and why it means what it means. To let people know, it just seems like a lot of decisions are made without educations, with a perspective that has no basis other than they learned it from someone, or they heard it, or it was repeated a lot of times in a situation that maybe is an emeritus one. Management, now that I am in management I see the need for science underneath some of what we do and some of that science mandates that we change what we do. And so, management shouldn't be just a series of protocols and formulas that are not based on some truth and reality on how systems work. And, because this is a water exercise I am thinking about weather, snowpack, glaciers that are here at the basis continental divide around the Shoshone, north to south. It is the continental divide that starts all of this off."
- Earlier runoff: "We got a request to do climate change study on one of our glaciers, it doesn't really matter the full source of the climate change. The fact is, I also studied geology and I know that things and systems change, and so, if this is a period of time that we are living in and things are going to change, I know it is going to change the big picture. It is going to change the big picture. So, the source is not as important to me as sort of the processes that are modified by changing climate. The species as they move upslope, that is something that I was just reading about, that species will be moving upslope as things get warming. So that is going to look a lot different in our top location where water starts for your project area."
- More frost-free days: "So in a way, science would be responsive to watching the changes. They would be responsive to studying, and keeping records, like you are giving me a span of records already about these frost free days, well that was done because people were paying attention, tallying, recording, and they were able to look back at records and just sort of watch. Again, to me if education can be based a lot more on science I think it makes a lot more in roads to a broader spectrum of people because you are not basing it on something that you are trying to achieve or something that you are trying to slant. You are really trying to show some science, which people here understand the medium temperature, they understand, that is a really easy thing to measure and talk about for high water, low water temperature, or not."
- Rapidly melting glaciers: "Definitely. I wish that I had been able to see some of those first hand, but I have seen some photographs of some glaciers that are definitely receding. What is interesting, my short time here just to watch how long and how high the water was coming off that Lake Louis area. We couldn't even ford this Torrey Creek till like

September last year, we had high water June, July, August. It was just pouring, and it wasn't rain it was just snow and glaciers."

- Increasing minimum temperatures: "Right, sort of like we covered just a minute ago. If these are changes, it is just changes. And species have gone extinct because of climate change in the past, and I expect that it is nothing that we can totally modify ourselves because these are natural process. Especially at headwaters and the high elevations, the temperatures are what they are going to be. I cant believe how strong the wind is here in the winter and that provides, and even though generally it is a melting event wind, it also adds a degree of coldness to the air. I am curious to know how that wind chill works at high elevation around here, it is very cold when that wind blows in the wintertime, but it is a wind, so I am wondering how that affects things and that is how that glacier study would be kind of neat to see how they do it in the summer, but it might be interesting to propose to them to put something there in the winter."

Conservation of rare plant species

- "Well, it might be harder for me to say this because I am not a plant person, but I have been in high places, high tundra places where a lot of the plants haven't even been identified or studied. The fact that these plants are there in this incredible harsh environment, I see a lot of benefit to knowing about them because maybe they are going to be helpful down the line as things change, but also just because of themselves there is something just spectacular. A lot of times those tundra plants are tiny, tiny, tiny, and you just are fighting thunderstorms and wind and you are just moving through there and not taking the time to learn what is underneath your feet. There is just a lot of proliferation at that level."
- Earlier runoff: "Yeah, earlier runoff just means that the water is leaving the high country faster and earlier. So the translation that I would make is the reservoir of water would be absent from certain places where these rare plants would be, say in a higher location. Again, I was sort of ranking by elevation. Earlier runoff just means that the reservoir of winter snow is gone faster, and of course it can be kept in some reservoir settings. But it is not like reservoir settings down there bring the water up back up here."

Participant #93
Nutrient cycling and sediment transport (Unprompted mention of climate change)

- "Probably number one would be climate change. If we have increased oil and gas production on the Shoshone, I think there is possibility with extracted water and effluent holding ponds and that kind of thing to impact that. You know, the entire extraction process has the ability to disrupt appropriate cycling and sediment transport. But climate change, I think would be number one, and oil and gas we are working on limiting."
- Earlier runoff: "You know I mean this year is a tough one to use as a judge. I think this is a tough one, you know, I think people, I think the mistake we have made with climate change in the past we have been rushing to attribute climate change to perturbations whether or not there was mathematical evidence to indicate if there was a trend that could be sustained over the long term. So I think it is my first year in this ecosystem, so I cannot really answer except to say that obviously we have an unnaturally warm winter. But how that will pan out, whether that is just a unique situation, or whether we are going to start seeing overall trends, but I think that the studies and science coming out of the Shoshone. The Shoshone is

our pilot climate change forest have indicated that there have been increasing temperatures which have led to earlier runoff."

- Rapidly melting glaciers: "Oh definitely, 100 percent. Both. I mean it certainly has the ability to impact stream temperatures and flow, and speed of flow and sedimentation, and even the entire micro habitat within those streams and how that impacts fish and organisms and stuff."
- Increasing minimum temperatures: "yeah, I mean I think because if minimum temperature is increasing it is obviously going to cause snowpack to melt quicker, less development of snowpack is going to directly affect cycling and sediment transport."

Biodiversity conservation (Unprompted mention of climate change)

- "I would say impacts, climate change and invasive species. Lake trout and hybridization with non-natives. Invasives, climate change, and then also related to development within particular sensitive areas, particularly oil and gas development. We have the impacts of produced water and that type of thing impacting those habitats."
- More frost-free days: "Definitely. We were talking about this internally, you know, perfect example that I was loosely involved in years ago. With few frost-free days, tree berries were not able to stop fermentation of those tree berries and we were losing song birds to ethanol toxicity. So I have literally a blanket of dead cedar waxens in my yard right now from ethanol toxicity because our trees just did not get cold enough to prevent fermentation of those berries. So I think there are all these ancillary costs, and just one to ten frost free days can have significant impact in terms of these minor issues like ethanol development in tree berries. In the process, I was writing a story for us to publish on this issue, and I just happened to be doing some research on some of the more recent studies. And really where they are looking at climate change in terms of having the most impact is on the wine industries, because alcohol contents have grown in red wines one percent per year and the only way, they are going to have to basically shift their entire development to keep those alcohol contents within the spectrum of what they are legally allowed to keep them in, and also taste is a component of that. So, I mean, climate change could theoretically destroy wine as we know it."

Participant #94

Biodiversity conservation (Unprompted mention of climate change)

- "Like is a climate change comes into affect and you have shifting amounts of precip and snowpack, that is going to affect a lot of different species, whether it be plants, animal, fish. That is the angle. In terms of conserving stuff in the greater Yellowstone, that is very important to me."
- Earlier runoff: "Right now, it depends on the degree of the earlier runoff. Four days earlier doesn't make that much difference, but if you did it a month or six weeks that influences the growth of crops, that sort of thing."
- More frost-free days: "Oh yeah, in terms of crops and stuff, bark beetle, insect disease type spread."
- Rapidly melting glaciers: "Yeah it does, it affects both because of the slow release of water in glaciers, and their reserve, it is like other environments and you know, Asia and stuff where they are seeing communities change, or in South America where they are seeing people running out of water earlier."

- Increasing minimum temperatures: "Yeah, definitely it is going to cascade."

Preservation of livelihoods, lifestyles, and landscapes (Unprompted mention of climate change)

- "Again, climate change and stuff, water flows, yields will change. That will in turn affect the different types of crops in the basin, and it will affect things like soil salinity, all come into more play. You will see changes in crops, and that will have a big affect. But that is mostly related to the importance, I had that as the Buffalo Bill dam is to the Bighorn Basin. Or the Sunshine reservoir versus the crops down the Greybull, and that is why those were built."

Participant #95
Native American cultural and spiritual values

- "Were we are located, and the recreational area being situated partially in the Crow Reservation, the water resources are going to, how the water resources are managed. How high the water level is impacts directly the commercial business that goes through the Crow Reservation, at least in the Montana side of the Recreational Area. For most people to get to the river access you need to cross Crow Reservation and so, with the dam and with the use of water for recreation. How much water, what the quality of water affect directly their ability to earn a living, it also, there are a lot of stories and oral histories associated with the Bighorn River itself. It was a big controversy when the dam put in, because of some of those stories and spiritual significance. Some of the areas that are currently underwater have a great deal of spiritual significance to the native peoples here. Whether the water levels go up or down affects that, the quality of water the same thing. There are people that still drink from the water, they purify it, they use it in religious ceremonies. And that, too is going to impact them significantly. The history of people in this part of the country too is very reliant on the water resources, because we are in a high desert environment, so we have over 10,000 years of history that we know of here in Bighorn Canyon, so we know people have been here for 10,000 years. We have evidence of people moving and using this area as a trail, and it actually has to do with the Bighorn River because it was a stable source of water through history. So that is, it is still a pretty large impact to them, and they utilize the river and they revere the river as an important value. As a cultural anthropologist and an archaeologist here that is part of what we try to work with the tribes on is to be able to preserve and conserve their view of the water resources, and all the other resources in the park as well as managing them from both the natural and cultural perspective outside of the Native American interest."
- Earlier runoff: "Yes, cause it is going to change a lot of, not just specifically the tribes that are here, but in general a lot of spiritual and ceremonial use of areas, ceremonies are based on natural cycles, and so if we are changing the natural cycle then the time that that ceremony or that event occurred may then not be matching up with what the traditional cycle would be. So you wouldn't be able have certain herbs, plants and then also for the animals, if part of the ceremonies or the use, Bison hunts things like that, if those animals are having to come off the mountain earlier or go up later due to the runoff or the change going that is also going to affect the hunts, sustainability, the use of the resources."
- More frost-free days: "It is the same thing. You know with the frost free days too, a lot of the watershed in the Bighorn River is based on snowpack, and if you are having less frost-

free days there is potential, not always, that there maybe less snow in the mountains, there may be less water coming down which could have a direct impact on both of those."

- Rapidly melting glaciers: "I think it is the same answer, water is a really important part of life for tens of thousands of years and today, and it is also a direct affect on why we manage things the way we do."
- Increasing minimum temperatures: "Yeah, because you are once again increasing temperature, you are changing the ecosystems, you are changing the way the days, the plants, the animals, how everything is being affected. Both from a cultural and natural, you might think from a cultural standpoint some of this stuff has been here for thousands of years how is that going to affect it, it doesn't affect necessarily the old stuff, but it also could affect it from a standpoint of some of these cultural and spiritual values, I am talking about archaeological sites, where we may have materials at those sites that can be directly affected by change in temperature, by water, by dryness it may preserve or decrease the values that we have on those sites, and our ability to get more information from those sites to really tell us more about it is going to be affected by temperature changes as well as all of the natural, it all ties in together."

Education, management and science

- "Well, you know, part of the Park Service mission is to preserve and conserve and also to educate. A lot of what we do is educate, we are learning about the ecosystems. With the water resources here it affects both the cultural and natural resources that we manage on a day to day basis. The water levels, if they go down that reveals cultural sites that we didn't know about or have been covered. It also has an impact on the animals that utilize the river where it is now for drinking, mountain lines the Pryor Mountain horses, other smaller impacts. What the water level does, if we have a drought it is going to affect the animals, and it is going to affect our ability to management them, and it is going to also affect our ability to educate other people on how to best manage and work with the natural and cultural resources. In terms of water quality, it is the same issue, if the water quality in the river or the watershed goes down that is going to affect, once again, the wildlife, it is going to affect Native American usage, it is going to affect hiking, but it is also going to affect recreation. Part of Bighorn Canyon is used very much by boaters, fishers, some scuba divers come here and that is a big part of what we are, and so water quality makes a big difference in the health of those species that people are looking for. Also, it just changes, biology all of those are related to water, and also just from a land use area. Some of this area is also used for irrigation, some of it used by private land owners with in-holdings, and some people run cattle very close to the river there too. What the river does has a direct affect on both their livelihoods, and their ability to maintain their lifestyle as it is, which is something that the west has lost a lot of."
- Earlier runoff: "I think it does from the same effect because our education and management is based on what we know of the resources in the area, and if that is changing then that is going to affect the behavior of the plants, the animals, it is also going to potentially affect the different species that are going to be in this area. So that is going to change our ability to educate and have a good baseline of what is here, and what we should be expecting to know, especially with invasive. What is invasive and what is not? Because a little bit of this and that can really change an ecosystem dramatically."

Participant #96
Biodiversity Conservation (Unprompted mention of climate change)

- "I think increased drought, there has been quite a bit of drought on the Shoshone in recent years. And, that is predicted to increase, so that is going to limit water resources, combined with climate change leading to increasing melting of glaciers. The glaciers on the Shoshone are decreasing, and so, just the amount of water available on the Forest is decreasing. And, you know everything depends on water in some capacity. So not just loss of wetlands species and aquatic species, but terrestrial species. For instance, whitebark pine if they are drought stressed they are less able to withstand other stressors and more likely to die which then impacts a whole suite of other species and hydrologic cylces and what not. I think drought and warmer temperatures leading to loss of glaciers will you know, impact diversity across the board."
- Earlier runoff: "Yup, cause it will, it interacts with the life cycles, for instance the cutthroat trout, amphibians and other species. If you have peak runoff at the wrong time of the year it will interfere with spawning, you basically have too much water too soon, and then not enough water later. And then, you can also have creeks and stuff drying up later in the summer when species still need water, but there is none left."
- More frost-free days: "Yup, with biodiversity conservation more frost free days are these kind of longer summers. There are a lot of bears on the Shoshone, this isn't really related to water, but bears, grizzly bears are going into hibernation later and coming out sooner. They are interacting with humans more and thus getting killed more. Grizzly bears are a major biodiversity concern. I guess just that changing of seasons with any species that hibernates, same thing is happening and then also with species that are migrating to certain food sources, there is a lot of lack of sync happening between green-up and where the elk are, or just changes in where species need to be, and where they are."
- Rapidly melting glaciers: "Less water mean less biodiversity."
- Increasing minimum temperatures: "This relates directly to my thesis. An increase in average minimum temperature leads to an increase in mountain pine beetle, which leads to a loss of whitebark pine, which has all sorts of implications for biodiversity. You know, that increase in minimum temperature also impacting bear hibernation and any number of other species that are tied to climate in some other way."

Preserving livelihoods, lifestyles, and landscapes

- "You know, so much of the livelihoods and lifestyles of people who live in the Bighorn Basin and the Wind River Basin is tied to the water that comes off of the Shoshone, either people the agricultural community wouldn't exist without irrigation from the Shoshone River and the Bighorn River. The recreation community, fly fishing and whitewater rafting, guiding, are kind of two of the major recreation, and ice climbing but the ice isn't really, it is not like the river flow is affecting ice. There is a lot of water-based recreation on the Shoshone and that is sort of driving this alternate economy that is trying to take hold, particularly in Cody and Lander, not so much in the rest of the Basin. And so, without that then, you know, you do not have much left for people to do. There is oil and gas development, and even that, well that is limited by oil and gas resources available, and you can't frack without water. And so, all of these different economies in the basin are tied to water, and so then that impacts both peoples livelihoods and what they do for recreation. And then the landscape itself is shaped by water, it is really erosive soils and without big major floods coming through the way the landscape changes it will stop changing to some degree."

- Earlier runoff: "Yup, the Buffalo Bill dam like last year had a huge spring runoff, the dam couldn't hold all the water and yet they had to release a ton of water early in the season when the irrigators didn't need it, and then later in the season when they did need the water there was still plenty in the dam because it was such a big year. If time of runoff switches and the dam is filling up with sediment anyway, again you are not going to have the water when you need it for agriculture. Same for river recreation, or you know guiding companies or whatever, if they get their big whitewater flows too early when the tourists are not there because it is still snowing. You know, it is just not that great to go on a Wyoming vacation in May, then people will still go on river trips but it is not going to be the same experience, and then also fishing is also impacted by when the flows are."
- Rapidly melting glaciers: "Might have been the same study, but there has been a lot of press recently of how melting glaciers are leading to decreased flows and really impacting irrigators in the Wind River Basin, so that links to preserving livelihoods, lifestyles and landscapes. If you lose that agricultural landscape, what is going to replace it? It is going to be one of subdivisions? Probably not because there still wont be any water. Also, lifestyles not just agriculture but people go to the Wind Rivers to see the glaciers and recreate on the water that comes from the glaciers, and if that goes away then there is still pretty mountains but an important aspect of them is gone."
- Increasing minimum temperatures: "The community of Cody is really excited about having this little ski area at the east entrance of Yellowstone. I do not really see a future for sleeping Giant for snow, they lucked out last year and I do not think they did so well this year. If these communities are trying to come up with a year round economy based on recreation, they maybe need to look beyond winter recreation. Maybe year round fall recreation."

Appendix I: Z-scores (factor scores) and corresponding ranks for each water-based ecosystem service for factors A and B (derived from null and confounding Q-sorts) taken from PQMethod output

		Factor			
No.	**Statement**	A		B	
1	Water quality	1.55	2	0.10	15
2	Preserving livelihoods, lifestyles, and landscapes	1.54	3	0.79	7
3	Water for stock	0.13	15	-0.46	22
4	Commercial irrigation	1.35	6	-0.77	27
5	Oil and natural gas extraction, and mining	-1.49	34	-1.86	34
6	Commercial water-based recreation	-0.76	26	-1.28	31
7	Education, management and science	0.43	12	1.83	2
8	Household/municipal water	1.64	1	0.65	10
9	Hydropower	0.89	10	-1.28	30
10	Land-based hunting	-1.09	28	-0.53	24
11	Non-motorized ice and snow based recreation	-0.72	24	-0.76	26
12	River recreation	-0.43	20	-0.07	18
13	Fighting forest fires	-0.63	23	0.90	6
14	River-based fishing	-0.15	17	-1.09	29
15	Conservation of rare plant species	0.38	13	0.62	11
16	Conservation of keystone (critical) species	1.42	4	1.37	4
17	Manufacturing and industrial	-1.21	31	-1.34	32
18	Nutrient cycling and sediment transport	0.79	11	0.46	12
19	Physically and mentally challenging recreation	-1.10	29	0.07	17
20	Personal irrigation	0.16	14	-0.60	25
21	Motorized ice and snow based recreation	-1.28	32	-0.12	19
22	Lake, reservoir, and river-based hunting	-1.12	30	0.19	14
23	Lake/reservoir recreation	-0.18	18	-0.41	21
24	Recreation/leisure activities done near water	-0.39	19	0.07	16
25	Supporting of commercial land-based recreation	-0.98	27	-1.07	28
26	Native American cultural and spiritual values	-0.72	25	2.09	1
27	Biodiversity conservation	1.26	7	0.41	13
28	Glacier-based services	-0.59	22	0.72	8
29	Natural flood control	0.95	8	0.70	9
30	Lake/reservoir fishing	-0.50	21	-0.46	23
31	In-stream flow	1.37	5	-0.33	20
32	Gradual discharge of stored water	0.91	9	-1.44	33
33	Non-Native American cultural and spiritual values	-1.33	33	1.60	3
34	Inspirational and aesthetic values	-0.10	16	1.30	5